SECTION 3

DEPARTMENT OF DEFENSE WEATHER PROGRAMS

The Department of Defense (DOD) operates a military environmental service system to provide specialized worldwide meteorological, space environmental and oceanographic analysis and prediction services in support of military forces. This system directly supports all phases of military operations, from strategic planning to tactical operations. While the Army and Marine Corps each have a small specialized weather support capability, the Naval Meteorology and Oceanography Command and Air Force Weather are the primary sources of military weather products. The military weather services contribute to the national and international weather observing capability by taking conventional observations on land and at sea where there are no other conventional weather observing capabilities and where the observations are most needed to meet military requirements. In addition, DOD maintains specialized observing capabilities, such as the Defense Meteorological Satellite and Global Weather Intercept Programs, to meet unique military requirements. Observational data are sent by military communications networks to military and civil facilities in the United States and overseas.

UNITED STATES AIR FORCE

METEOROLOGICAL AND SPACE ENVIRONMENTAL SERVICES

Air Force Weather (AFW) provides high-quality, mission-tailored terrestrial and space environment observations, forecasts, and services to the United States Air Force (USAF), United States Army (USA), and a variety of United States Government (USG) departments and agencies. See Section 3, United States Army, for details of AFW support to the Army.

AFW ORGANIZATION

AFW is functionally organized under the Director of Weather (AF/XOO-W), Directorate of Operations and Training (AF/XOO), Deputy Chief of Staff for Air and Space Operations (AF/XO), Headquarters Air Force (HAF). The Director of Weather oversees Air Force-wide training, organizing, and equipping of AFW organizations to include the following functions:

- Development of doctrine, policies, requirements, and standards for weather support.
- Evaluation of weather support effectiveness.
- Management of weather officer, enlisted, and civilian career fields.
- Development and implementation of mid- to long-range plans for the organization, equipment, manpower, and technology necessary to meet future Air Force and Army weather requirements.

- Advising Air Staff and subordinate headquarters weather functional managers regarding manpower, career field management, personnel utilization, training, operations policy and procedures, and technology acquisition.
- Advocating and fielding standardized weather equipment.

AFW, a Total Force capability, employs over 4,400 Active and Reserve Component (AC and RC) military and civilian personnel supporting Air Force and Army conventional and special operations forces (SOF) at more than 290 locations worldwide. The majority of AFW personnel are focused on two distinct, yet related functions: characterizing the past, current, and future state of the natural environment and providing responsive weather and weather impact information directly to decision-makers. Environmental characterization is typically accomplished in large, centralized units focused primarily on global and regional scales of weather, whereas support to decision-makers is primarily the realm of personnel embedded in operational units. Normally, these personnel are assigned to weather flights under the operations support squadron of a flying wing, a weather squadron collocated with a supported Army unit, or a weather squadron providing a unique capability such as space launch support.

These weather squadrons may include geographically separated detachments and operating locations.

The centerpiece of global-scale collection and production is the Air Force Weather Agency (AFWA), Offutt AFB, Nebraska, a field operating agency (FOA) reporting directly to the Air Force Director of Weather. AFWA provides timely, accurate, relevant, and consistent terrestrial and space weather products necessary to effectively plan and conduct military operations at all levels of war. AFWA also provides dedicated support to SOF and the National Intelligence Community (NIC). The agency consists of a global processing center collocated with a functional management headquarters, two subordinate centers (the Air Force Combat Climatology Center (AFCCC) and the Air Force Combat Weather Center (AFCWC)), and 11 detachments and operating locations. AFWA also provides backup support to five national weather centers. AFCCC, Asheville, North Carolina, provides centralized climatological database services, produces specialized weather-impact information for DOD and allied nations, and warehouses and distributes atmospheric science-related technical information. From Hurlburt Field, Florida, AFCWC transitions technology to support tactical-level weather operations while developing operational concepts, tactics, techniques, and procedures.

Eight operational weather squadrons (OWS) form the backbone of regionally focused weather operations, providing a variety of weather forecast products and support to units assigned and/or deployed into their area of responsibility (AOR). These AORs are depicted in Figure 3-DOD-1. OWSs produce and disseminate terminal aerodrome forecasts (TAFs), weather watches, warnings, and advisories, planning and execution area forecasts, and other products using the OWS Production System Phase II (OPS II). OWSs also provide theater-scale, tailored environmental information to guide development of mission execution forecasts (MEF) by AC and RC weather personnel embedded in operational units. Moreover, OWSs provide flight weather briefings to aircrews operating within their AOR without home station support or as requested by base or post-level weather forces. When collocated, OWS personnel also support the commanders and staffs of numbered air forces (NAFs) and air and space operations centers (AOCs).

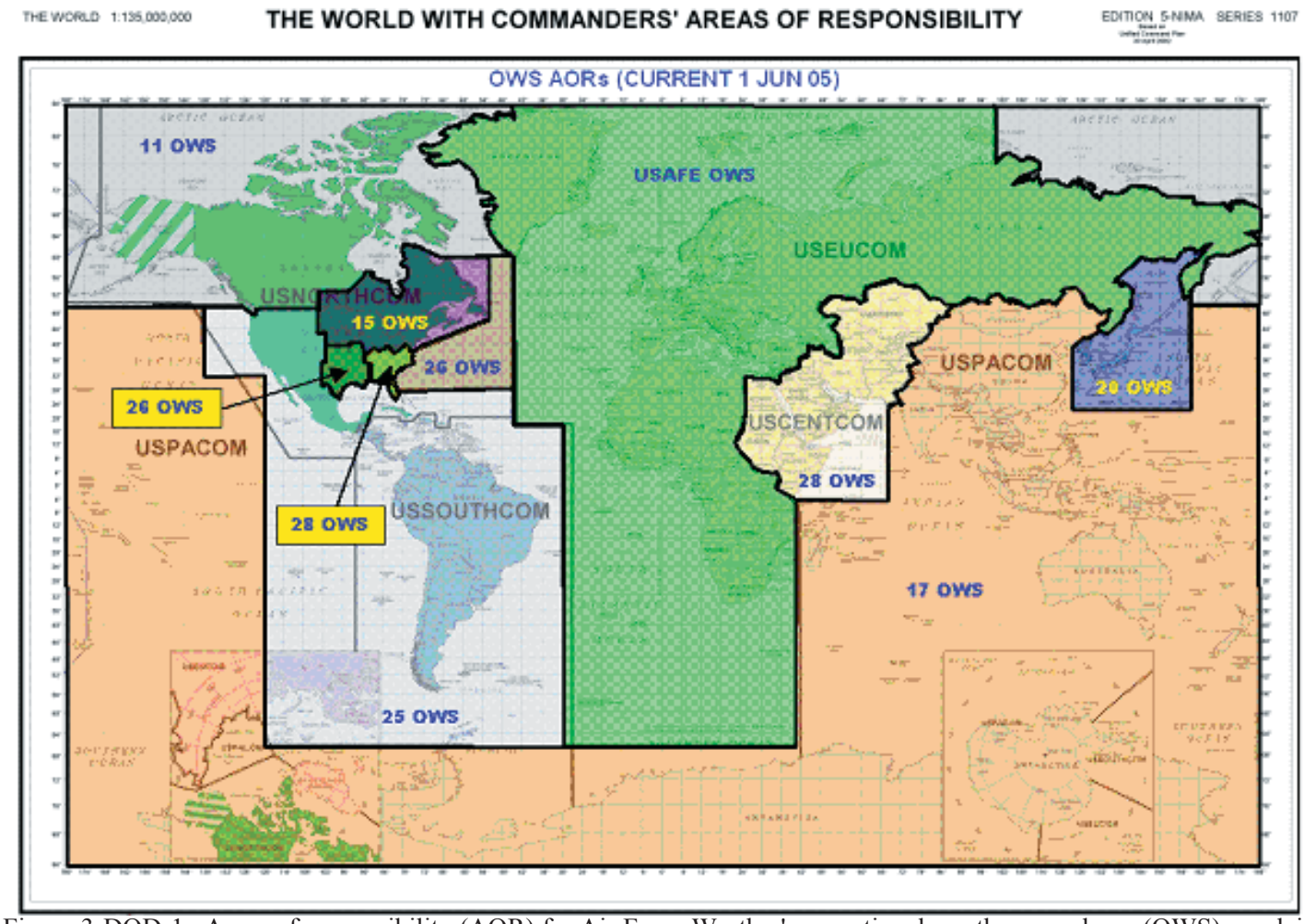

Figure 3-DOD-1. Areas of responsibility (AOR) for Air Force Weather's operational weather squadrons (OWS) overlaid on geographic combatant commander AORs.

At base and post level, weather forces take and disseminate local observations and develop tailored MEFs based on centrally produced guidance. These personnel also act as "eyes forward" for OWSs. Weather personnel deploy with a New Tactical Forecast System (N-TFS), hand-held Kestral observing kits, and the TMQ-53 semi-automated observing system for semi-permanent sites. This equipment, coupled with adequate communications to receive weather data, including satellite imagery, provide the essential capability required for deployed weather forces to meet operational requirements.

The RC is composed of the Air Force Reserve (AFR) and the Air National Guard (ANG), and AFW continues to reengineer these forces to more closely align with AC weather operations. Air Force reservists augment the AC at all levels. To augment OWSs, Air Force Reserve Command recently organized two operational weather flights (OWF), each with just over 20 traditional reserve positions. The OWF traditional reservists perform at least one weekend of drill monthly and 2 weeks of duty each year unless mobilized to the active force. Approximately 50 additional weather personnel serve as AFR individual mobilization augmentees (IMAs) assigned to various active AFW organizations at all echelons, typically in staff or scientific roles. IMAs normally train 1 day each month and for an additional 2 weeks each year.

The ANG traditional program consists of 33 weather flights, ranging in size from 13 to 25 personnel, who meet monthly to train for their wartime mission. These flights provide weather information to Army National Guard and United States Army Reserve units as well as ANG flying units. In addition, the ANG performs peacetime weather operations at locations where the ANG is responsible for airfield support. The Weather Readiness Training Center (WRTC) at Camp Blanding, near Starke, Florida, is also operated by the ANG to provide Army tactical skills training.

CHARACTERIZE THE ENVIRONMENT

To characterize the environment across the globe, AFW continually improves the core processes of collection, analysis, and prediction.

Collection

AFW collects terrestrial and space environmental measurements from ground-, sea-, air-, and space-based sensors across the globe. While openly shared foreign data greatly improves the coverage of measurements across the globe, the Department of Defense retains an assured global weather collection capability. In regions where air, space, and land operations are occurring, environmental data may be insufficient; consequently, AFW maintains a capability to deploy in-theater to establish an environmental data collection network.

AFW personnel take observations essential for effective military operations and for weather analysis and forecasting. Weather personnel at both Air Force and Army locations (garrison and deployed) make observations available to local users and transmit them to military and civil locations throughout the world. United States and foreign rawinsonde reports are primary sources of upper air observations and are supplemented with military and civilian pilot reports. The Army's Forward Area Limited Observing Program (FALOP) and the Army artillery meteorology (ARTYMET) program augment Air Force observations in the tactical environment. Weather data is also received from DOD-operated HF radio receiver sites strategically positioned around the globe to intercept weather broadcasts. These broadcasts originate from nations that do not routinely make data available through World Meteorological Organization (WMO) channels.

The Observing System 21st Century (OS-21) program will provide a much-needed, state-of-the-art life-cycle replacement for Air Force observing equipment. OS-21 includes five different configurations: fixed, deployable, remote, manual, and upper air. The manual configuration is intended for tactical operations and continues the improvements begun under the Manual Observing System and Tactical Meteorological Observing System Modification programs. AFW began fielding the fixed-base automated observing system and will continue to do so through 2006. The remaining configurations will be upgraded or replaced after fielding of fixed-base automated systems nears completion.

Weather radar data is vital to the production of timely severe weather warnings. DOD, the Federal Aviation Administration (FAA), and Department of Commerce (DOC)/National Weather Service (NWS) operate and maintain WSR-88Ds within the Continental United States (CONUS), and the Air Force operates and maintains those that are overseas. The Air Force is transitioning to the network-connected open architecture Open Principal User Processors (OPUPs) at installations with stand-alone legacy PUPs and at all CONUS OWSs, allowing these regional forecasting centers real-time access to WSR-88D radar data at locations for which they have remote forecasting responsibility. Tactical weather radars (TWR) and Ellason weather radars (EWR) provide a deployable weather radar capability for worldwide military contingency operations.

The Air Force Reserve Command's 53d Weather Reconnaissance Squadron (53 WRS), also known as the "Hurricane Hunters," provides another means of collecting vital meteorological data, especially in and around tropical cyclones. Their specially equipped WC-130 aircraft collect tem-

perature, moisture, wind, pressure, and visually observed information at the aircraft location as well as vertical profiles of the atmosphere collected by dropsondes. Hurricane Hunter aircraft penetrate the eyes of tropical cyclones to provide the National Hurricane Center a very accurate center fix location as well as other meteorological parameters, including sea level pressure (Figure 3-DOD-2). In addition to the tropical cyclone reconnaissance, the 53 WRS collects meteorological information to improve wintertime West Coast forecasts and to support scientific field programs when possible.

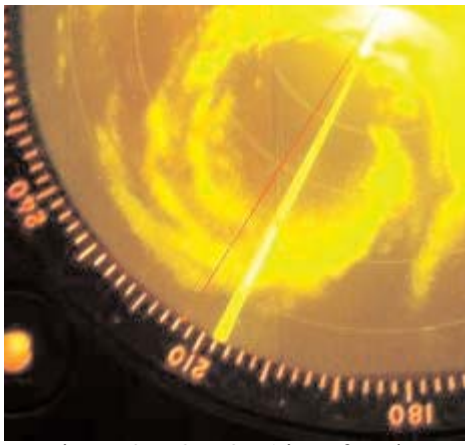

Figure 3-DOD-2. Aircraft radar shows the eye of Hurricane Claudette is 25 nautical miles wide and the wall cloud is weakest in the northeast quadrant (53 WRS website)

The Defense Meteorological Satellite Program (DMSP), which provides cloud, upper air, and space environmental data, is a vital source of global weather data used to support combat operations. On-board sensors provide AFWA and the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) with visible, infrared, and microwave imagery, temperature and moisture sounding data, electrically-charged particle fluxes, and other specialized space environment data. The DMSP also supplies direct, real-time readout of regional imagery and mission-sensor data to DOD land-based and shipboard terminals located worldwide (Figure 3-DOD-3).

The present DMSP satellite series (Block 5D-2) uses the Operational Linescan System (OLS) to provide visible and infrared imagery to distinguish between clouds, ground, snow, and water. The DMSP also flies the Special Sensor Microwave Temperature (SSM/T) and water vapor (SSM/T-2) sounders. Processing algorithms convert the sensed data into vertical temperature, moisture, and height profiles of the atmosphere, providing key data for numerical analysis and forecasting. The Special Sensor Microwave Imager (SSM/I) observes rainfall, ocean surface wind speed, cloud and soil moisture, ice conditions, and other environmental data. The Special Sensor for Ions and Electrons (SSIES), Special Sensor Magnetometer (SSM), and the Precipitating Electron and Ion Spectrometer (SSJ), each providing vital inputs to space weather models, measure the space environment on the topside of the ionosphere in situ. The Block 5D-3 spacecraft and sensor suite began service in 2004 with the launch of DMSP Flight 16. These spacecraft add several new capabilities: enhanced microwave imaging and atmospheric temperature/moisture sounding through the Special Sensor Microwave Imager/Sounder (SSMIS); new auroral boundary and electron density measuring capability through the Special Sensor Ultraviolet Spectrographic Imager (SSUSI); and profiles of upper-atmospheric temperature, electron content, and species densities through the Special Sensor Ultraviolet Limb Imager (SSULI).

AFW continues to participate in the refinement of requirements for the National Polar-orbiting Operational Environmental Satellite System (NPOESS). NPOESS will replace the existing DMSP and NOAA polar-orbiting satellite programs beginning in 2010, and is a joint DOD, DOC, and National Aeronautics and Space Administration (NASA) program. A ground terminal system will also provide a direct readout capability for regional/local users similar to that of the DMSP. AFW also expects to gain operational experience as well as benefit from the risk reduction planned with the NPOESS Preparatory Program planned for launch in 2008.

In addition to DMSP polar-orbiting data, AFWA receives stored data from the DOC's Polar-orbiting Operational Environmental Satellite constellation and real-time high-resolution data from the DOC's Geostationary Operational Environmental Satellite (GOES) East and West; the European Union's Meteosat-5, -7, and -8 geostationary satellites; and GOES 9, currently filling the Far East geostationary orbit until AFW transitions to the Japanese Multi-functional Transport Satellite (MTSAT). NESDIS receives test data files from India's INSAT-3A and KALPANA-1 (formerly METSAT-1) geostationary satellites. AFWA plans to accept this data via the Shared Processing Program (SPP) once data geolocation is improved to the appropriate level. AFWA currently receives data from NASA's Tropical Rainfall Measuring Mission (TRMM), Quick Scatterometer (QuikSCAT), and Moderate Resolution Imaging Spectrora-

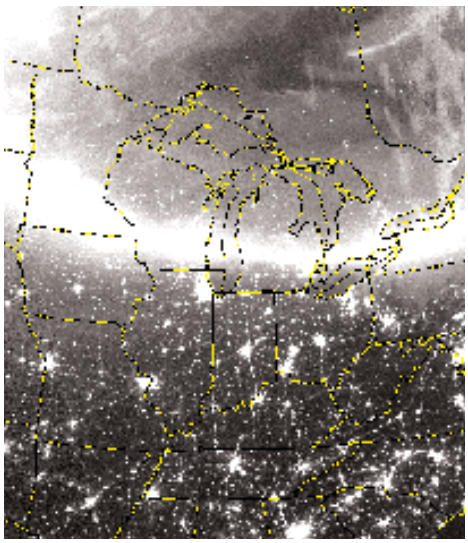

Figure 3-DOD-3. DMSP captures Aurora Borealis, over the midwest; the aurora was pushed toward the equator by a November 4, 2003 geomagnetic storm. (AF Weather website)

diometer (MODIS) via the SPP.

AFW implemented the Joint METSAT Imagery, Software, and Terminals (JMIST) capability to receive real-time visible, infrared, and microwave imagery and other non-imagery weather data from both polar-orbiting and geostationary satellites. JMIST employs network and satellite communications, direct read-out terminals, and client applications to provide ready access and manipulation capabilities for advanced low-orbiting satellite imagery from numerous agencies, to include the US Air Force, US Navy, and NASA.

Space environmental information is obtained through a combination of ground- and space-based systems. For the near-Earth environment, ground-based systems provide highly accurate point source verification and specification, whereas space-based systems enable global coverage and theater-wide situational awareness.

AFWA operates the Solar Electro-optical Observing Network (SEON), a system of ground-based telescopes at Sagamore Hill, Massachusetts; Holloman AFB, New Mexico; Palehua, Hawaii; San Vito, Italy; and Learmonth, Australia (Figure 3-DOD-4). This network provides 24-hour observations of solar phenomena at optical and radio wavelengths.

Figure 3-DOD-4. Solar optical and radio telescopes at Learmonth, Australia.

A worldwide (primarily Northern Hemisphere) network of ground-based ionosondes and other sensors provide ionospheric data. AFW manages 17 automated Digital Ionospheric Sounding Systems (DISS) to measure electron density profiles in the ionosphere. NASA's Jet Propulsion Laboratory (JPL) operates a complementary global network of sensors deriving ionospheric line-of-sight Total Electron Content (TEC) from GPS signals and provides this data to AFWA's Space Weather Branch. In addition, the United States Geological Survey (USGS) operates a network of ground-based magnetometers, primarily in the Northern Hemisphere, which provides the Space Weather Branch with critical measurements of the geomagnetic field and its variances. AFWA receives JPL and USGS data from NOAA's Space Environment Center (SEC), Boulder, Colorado.

From space, the GOES meteorological satellites provide real-time solar X-ray, charged energetic particle, and geomagnetic data through the SEC. The Solar X-Ray Imager (SXI), which became operational January 30, 2003, aboard GOES-12, monitors solar emissions in the extreme ultraviolet (EUV) and X-ray portions of the solar spectrum and provides near real-time display at AFWA and the SEC. DMSP, NOAA, and other DOD geostationary satellites provide charged energetic particle data in low-Earth and geosynchronous orbits. Additionally, AFW leverages space-based data from NASA and other agencies. For example, NASA's Advanced Composition Explorer satellite provides real-time solar wind data critical for forecasting geomagnetic disturbances and their impact to warfighter communications.

Analysis and Prediction

Effective analysis of collected terrestrial and space weather data enables identification of environmental features and conditions that may affect air, space, and land operations and thus require subsequent monitoring. From that analysis, detailed forecasts are developed through a combination of computer models and skilled human intervention.

AFWA's Global Weather Center Division is AFW's main production capability for global space and terrestrial weather analyses and forecasts. Worldwide conventional weather data are relayed to AFWA and combined with civil and military meteorological satellite data to construct a real-time, integrated environmental database. Computer programs further process the data to construct models of the atmosphere and forecast its future behavior. The Satellite Data Handling System (SDHS) facilitates the interaction between forecaster and machine.

The Division's Meteorological Satellite (METSAT) Applications Branch analyzes imagery, develops techniques, inserts technology, and recommends improvements to METSAT products. The branch produces rapid response, tailored METSAT imagery and evaluation for DOD contingency operations and generates automated METSAT imagery products for web-based distribution to DOD users. The branch also tracks and classifies tropical cyclones for the DOD Joint Typhoon Warning Center (JTWC) and the DOC National Hurricane Center; serves as the DOD focal point for volcanic ash plume detection, advisories, and trajectory forecasts; and provides back up for both JTWC satellite operations and the DOC's Washington Volcanic Ash Advisory Center. In addition, the METSAT Applications Branch produces worldwide snow and ice cover analyses to update and refine the snow depth database and generates customized snow depth and dust event

analyses for contingency areas.

During Operation IRAQI FREEDOM, branch imagery specialists provided high-resolution analyses of oil fire initiation points for smoke plume dispersion forecast model products. These smoke plumes impacted both air and land operations. Advance notice allowed mission planners to modify operations to maximize mission effectiveness. The branch also develops new capabilities to display and visualize satellite imagery on workstations and infuses state-of-the-art techniques into improved imagery analysis.

The Division's Space Weather Branch employs a suite of state-of-the-art space weather models to specify current solar and global characteristics, extrapolate space weather phenomenon to areas of the globe where observations are not currently available, and to forecast future conditions. These models use available observations and include both climatology-based and physics-based algorithms. More detailed descriptions of both the available observations and current models can be found in Chapter 2 of the *National Space Weather Program Implementation Plan, Second Edition*, available from the Office of the Federal Coordinator for Meteorology.

The Global Theater Weather Analysis and Prediction System (GTWAPS) is the hardware enclave (IBM Scalable Parallel Computing and pSeries® servers) used to run most meteorological models at AFWA. The key software component of GTWAPS is a theater analysis and forecast model, Mesoscale Model version 5 (MM5), which provides fine-scale forecasts (Figure 3-DOD-5).

During Operations ENDURING FREEDOM and IRAQI FREEDOM, AFWA initiated various model window locations and resolutions as mission requirements dictated. The highly responsive nature of the MM5, and the way AFWA employs it, permitted new contingency windows to be operational within hours. Advancements in cloud modeling have enabled GTWAPS to produce high-resolution products that became a mainstay of weather data during the continuing global war on terrorism. MM5 is routinely provided by AFWA to the NOAA National Centers for Environmental Prediction (NCEP), where it is a backup to their Eta model.

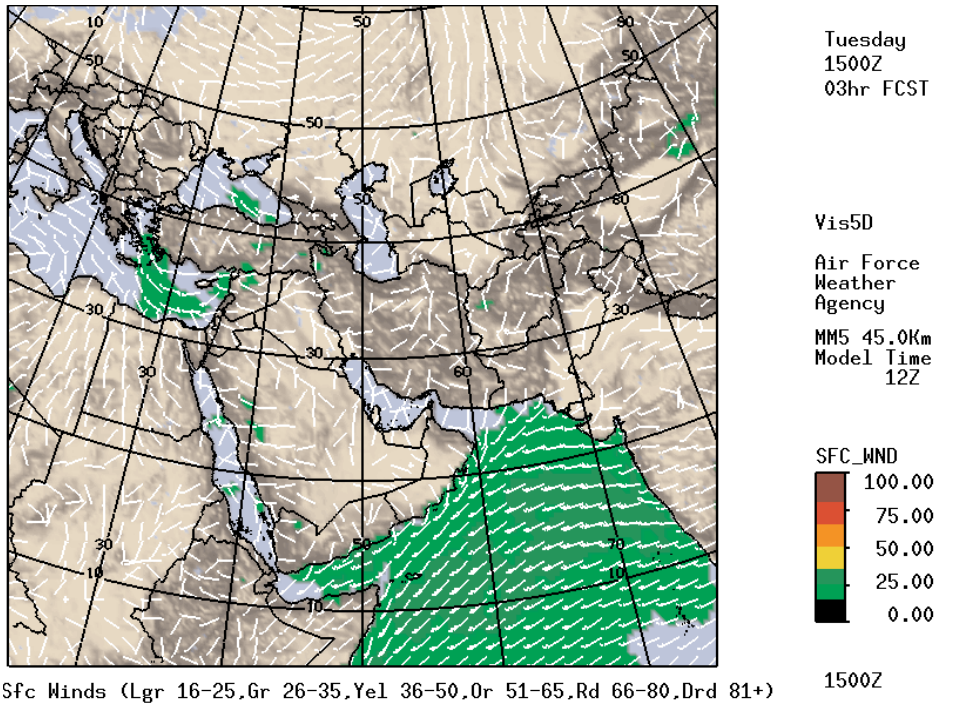

Figure 3-DOD-5. Joint Air Force and Army Weather Information Network (JAAWIN) provide reachback capability for deployed weather forces. This 3-hour forecast of surface winds over Southwest Asia was generated from AFWA's 45-km MM5 (AFWA Website)

On-going modernization initiatives at AFWA include the Space Weather Analysis and Forecasting System (SWAFS) and the Weather Data Analysis (WDA) program. SWAFS will integrate additional space weather data sources and execute next-generation space weather models for DOD and NIC operations. WDA will continue the modernization of AFWA as a key component of the Air Force Weather Weapon System (AFWWS). The reengineered AFWA will provide standards-compliant hardware and software tools, a central 4-D database, and a classified processing environment to modernize the AFWWS communications and data processing infrastructure. WDA provides a significant increase in the database capability by standing up Joint DOD-approved METOC database segments, promoting interoperability among data sharers. WDA, through the use of the METOC segments and the Joint METOC Broker Language for web services, will improve the interoperability with DOD command and control (C2) and command, control, communications, computer, intelligence, surveillance, and reconnaissance (C4ISR) systems by providing a common interface to request the wide range of weather information. In addition, WDA-developed components (to include the Consolidated Dissemination Capability) are reusable within the OWS. This reusability will allow OWS-unique data to become part of the overall AFWWS 4-D database.

The Air Force Combat Climatology Center (AFCCC) is collocated with the National Climatic Data Center to facilitate cooperation and data exchange. AFCCC collects, quality assures, and assesses worldwide surface and upper

air observations, satellite-derived soundings, numerical model output such as global gridded surface and upper air model data, a global 3-dimensional cloud analysis (worldwide merged cloud analysis), a global analysis of snow cover, and other specialized environmental data sets. AFCCC exploits these data to generate standard climatic summaries of meteorological phenomena for points around the globe, such as Operational Climatic Data Summaries and Wind Stratified Conditional Climatologies. Modeled climatologies are produced using the Advanced Climate Modeling and Environmental Simulations model. Analysts are available to develop tailored products to meet new requirements. AFCCC employs the Atmospheric Slant Path Analysis Model (ASPAM) to produce vertical profiles for any point on Earth for any time since 1985.

The Air Force Director of Weather is the DOD's Air and Space Natural Environment Modeling and Simulation Executive Agent (ASNE MSEA). The Director executes this responsibility through the ASNE MSEA office, a division within AFCCC (AFCCC/SM). The executive agent is responsible for ensuring modeling and simulation developers and users have the tools, infrastructure, and databases necessary to represent the air and space natural environment. AFCCC/SM sponsors research and development and fields technology at AFCCC, the designated center providing tailored atmospheric data for modeling and simulation. In cooperation with the National Geophysical Data Center (NGDC) and the Defense Modeling and Simulation Office (DMSO), AFCCC/SM also sponsors ongoing research to develop a similar capability to provide tailored on-demand representations of the space environment.

OWSs are AFW's regional/theater analysis and forecast centers for Air Force and Army operations. OWSs generate a variety of products: hazard charts; drop zone, range, and aerial refueling track forecasts; fine-scale target forecasts; airfield forecasts; and weather warnings, watches, and advisories for Air Force and Army installations within their AOR. OPS II, a component of the Forecasting System 21st Century (FS-21) program to provide necessary computer hardware and software throughout the AFWWS, is the OWS's primary production tool. A hybrid of software, databases, servers, and workstations, OPS II facilitates production and dissemination of weather information to supported forces.

Provide Actionable Environmental Impacts Information to Decision Makers

To provide actionable environmental impacts, AFW continually improves the core processes of tailoring and integration.

Tailoring. Once centralized weather units create a depiction of the past, current, and future state of the natural environment, AFW forces directly supporting decision-makers tailor the information to identify impacts to operations, personnel, weapons and weapons systems, and tactics. These weather forces then help decision makers mitigate these effects through appropriate actions such as routing a flight to a new target, selecting a different weapons load, or adjusting the time of attack.

N-TFS, another component of FS-21, provides garrison and deployed weather forces with the meteorological tools to manipulate and disseminate graphical and alphanumeric products (satellite imagery, graphical forecast products, weather forecasts, advisories, briefings, observations, etc.) to Army and Air Force operational, C2, and support forces worldwide. Additionally, N-TFS ingests data from Air Force and indigenous observing sources, which then are forwarded to OWSs/AFWA for further dissemination and incorporation into centrally produced models.

AFW is currently working toward a single workstation that integrates both the Army's Integrated Meteorological System (IMETS) and the Air Force's N-TFS while providing the necessary interface capability for C2 systems. The Joint Environmental Toolkit (JET) is expected to enhance warfighter awareness of the natural battlespace environment by ensuring accurate, timely, relevant, and consistent terrestrial and space weather and weather impacts information is available and accessible by appropriate personnel and processes. JET will fulfill this role by providing a single common forecaster interface to the virtual Joint METOC Database (JMDB) for use at all levels of the AFWWS support structure. JET integrates with Joint and coalition C4ISR/Mission Planning (MP) systems by enabling machine-to-machine exchange of METOC data and information to meet operational planning and execution requirements. Furthermore, JET enhances the accuracy and utility of terrestrial/space weather and oceanographic information and operational impacts by enabling the forecaster and/or forecast process to incorporate Geographic Information System (GIS) capabilities (to include a standard high-resolution topographic database), forecasting rules of thumb, and operational thresholds into weather and weather impact products. In July 2004, two contractors were selected for a 15-month fly-off. The down select to one contractor is projected for October 2005, with fielding of the first increment to begin in late 2006. Expected delivery of all JET capabilities is FY 2013.

Tactical Decision Aids (TDAs) provide warfighters an automated way to "visualize" environmental impacts on operations. These tools, which continue to be integrated into command and control systems (e.g., mission planning systems), include Target

Acquisition Weapon Software (TAWS) (Figure 3-DOD-6), Infrared Target Scene Simulation (IRTSS), and Tri-Service Integrated Weather Effects Decision Aid (TS-IWEDA). The Air Force Research Laboratory (AFRL), the Navy's Space and Naval Warfare Systems Command, the Navy Research Laboratory (NRL), and the Army Research Laboratory (ARL) are developing these modular programs.

TAWS provides a joint mission-planning tool to combine platform, weapon, target, background, and weather impacts to depict 3-dimensional target acquisition and lock-on range and recognition range versus time. This includes prediction of environmental impacts on night vision goggles and low light-level systems used by air, naval, and ground forces to execute nighttime operations.

IRTSS uses detailed terrain information and multispectral imagery with TAWS weather inputs to generate forecast target scene images for mission rehearsal.

The TS-IWEDA uses environmental data with force, mission, and/or individual weapons rules of engagement or performance parameters to automatically generate mission-impact forecasts for large-scale planning efforts such as Air Tasking Order preparation. TAWS, IRTSS, and TS-IWEDA integrate environmental impacts into the mission execution forecasts for C2 and MP systems throughout the military planning and execution cycle.

The TDA program continues adding weapons systems and targets at the request of users from the Services. Additional decision aids in development or in coordination include the Airborne Laser (ABL) Atmospheric Decision Aid (ADA) to support ABL development and operations and a common radio frequency (RF) system performance prediction capability based on US Navy software.

AFWA's Special Support Operations Branch (SSOB) generates a myriad of products ranging from air refueling forecasts, to detailed mission control forecasts, to weather impacts for SOF operations, and distributes this information via secure media to support worldwide Joint SOF operations. The branch also provides tailored meteorological information for end-to-end planning at US Special Operations Command (USSOCOM), Service component special operations commands, and theater special operations commands. The SSOB is continually involved in global military operations, including Operations ENDURING FREEDOM and IRAQI FREEDOM. Additionally, the SSOB includes the American Forces Network Weather Center, which provides worldwide, broadcast-quality public weather services and planning forecasts through the American Forces Radio and Television Service to over 1,000,000 DOD and Department of State personnel and family members stationed overseas.

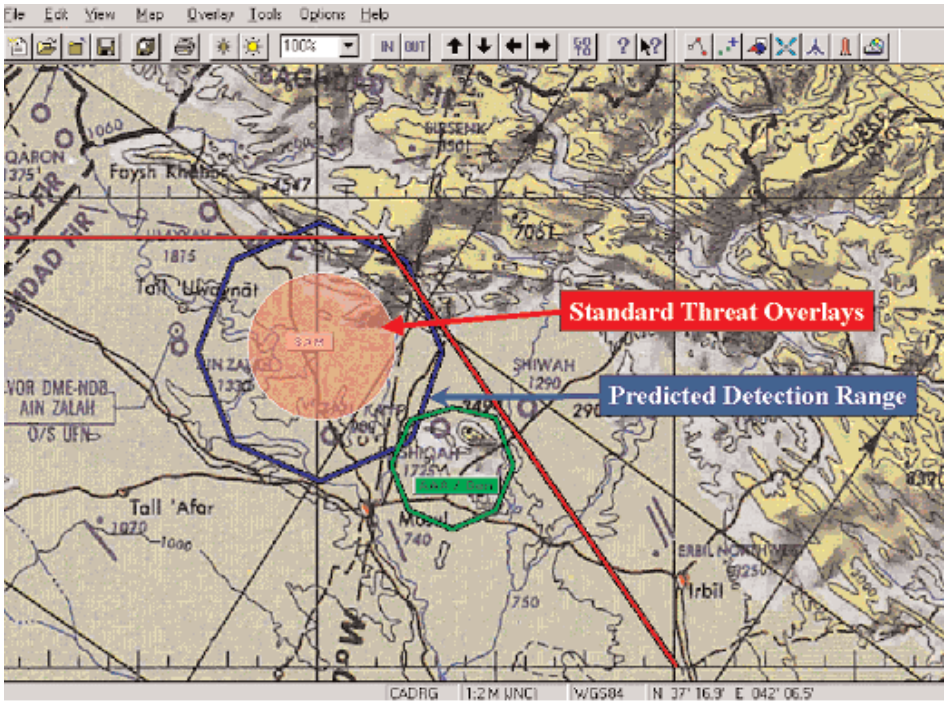

Figure 3-DOD-6. Target Acquisition Weapon Software (TAWS) integrate meteorological conditions and environmental parameters to enhance the mission planning process and increase aircrew situational awareness for mission execution.

AFWA's NIC Weather Branch provides detailed global cloud analyses and forecasts to the intelligence community. The branch provides worldwide mission-tailored planning and execution forecasts for NIC agencies at security levels up to Top Secret/Sensitive Compartmented Information (TS/SCI). The branch also serves as the focal point for AFWA Special Access Program (SAP) requirements; ensures the NIC and other SCI and SAP meteorological requirements are integrated into AFWA programs; monitors and evaluates accuracy and timeliness of centralized weather services to the NIC; and interfaces with the DOD and NIC regarding weather services and the exploitation of weather information.

As the sole source of DOD space environmental information, AFWA partners with NOAA's SEC to meet the nation's military and civilian space weather needs. AFWA's Space Weather Branch provides a suite of automated and manually tailored analyses and forecasts (including advisories and warnings) of space weather phenomena that affect military operations and National Intelligence Com-

munity (NIC) activities. Similarly, signal fades due to space weather effects on UHF satellite communications (SATCOM) links provide valuable planning information to improve command and control capabilities. Further examples of model output informational products include Single-Frequency GPS Receiver Error maps (Figure 3-DOD-7), UHF Satellite Communication Scintillation maps (Figure 3-DOD-8), HF Illumination maps (Figure 3-DOD-9), and Radar Auroral Clutter maps. These products assist warfighters in determining and mitigating space weather impacts to their systems as well as in exploiting enemy space weather susceptibilities for possible asymmetric advantage.

The Air Force provides meteorological and space weather products to the nation's space and missile programs, including a wide range of weather observing services at the Air Force Eastern Range and the Kennedy Space Center (KSC). The Air Force also provides tailored forecasting for NASA's manned and unmanned launches and for commercial launches from KSC.

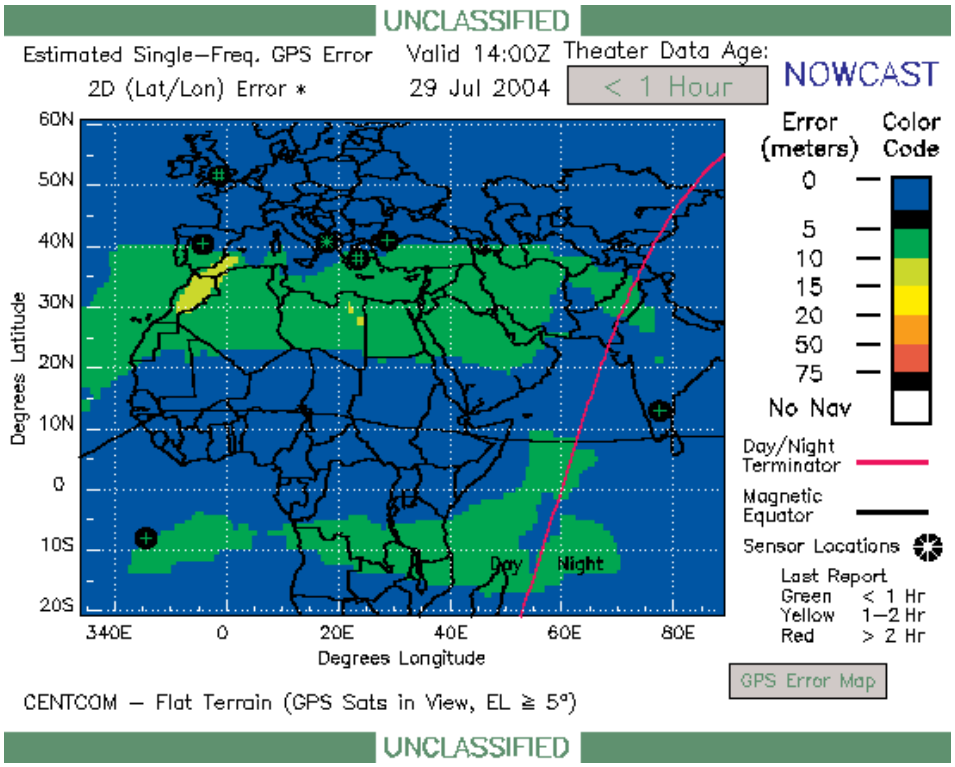

Figure 3-DOD-7. Single-Frequency GPS Receiver Error Map (visualized by HQ AFWA)

In addition, the Air Force provides specialized meteorological information for the Air Force Western Range at Vandenberg AFB, California; the Pacific Missile Range, which includes Point Mugu and San Nicholas Island, California, and Barking Sands, Hawaii; White Sands Missile Range, New Mexico; Kwajalein Missile Range, Republic of the Marshall Islands; and other DOD research and test facilities as directed.

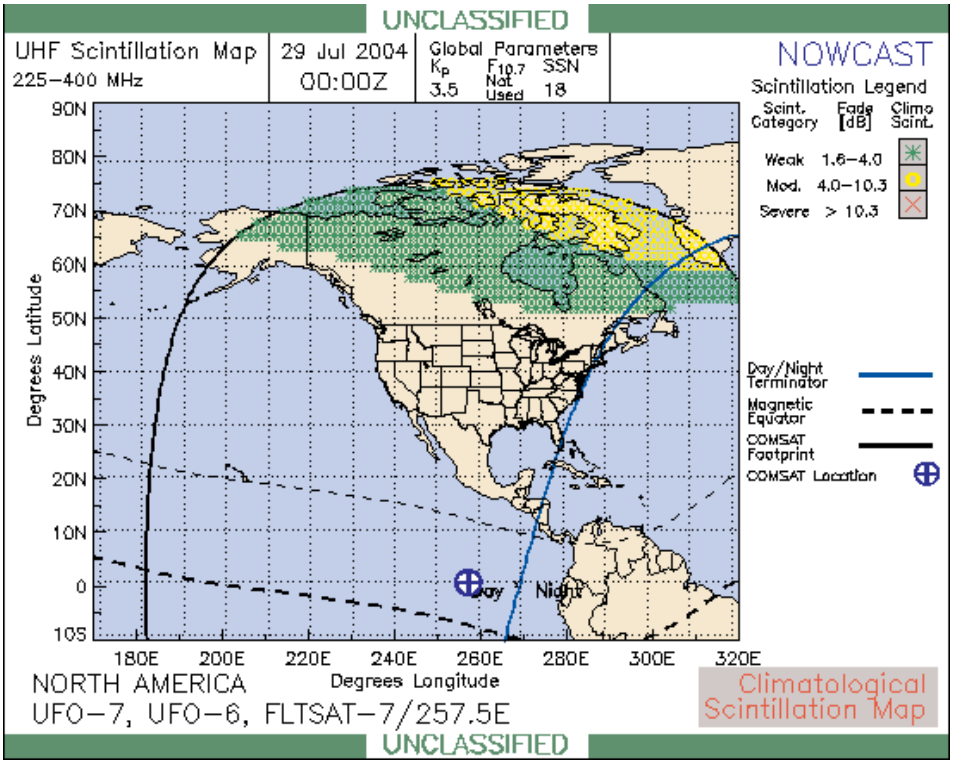

Figure 3-DOD-8. UHF Satellite Communications Scintillation Map (visualization by HQ AFWA)

The Air Force also provides agrometeorological support to the United States Department of Agriculture's Foreign Agricultural Service and other similar users. The output includes diagnostic soil hydrology and other meteorological information pertinent to crop growth and yield estimation as well as to trafficability and rudimentary flooding estimations.

Integration Tailored environmental information and operational impacts are of little use to decision-makers if the information/impacts are not integrated into the shaping, planning, execution, and sustainment of air, space and land operations. AFW employs a blend of information technology (IT), including automated machine-to-machine interfaces, and personnel

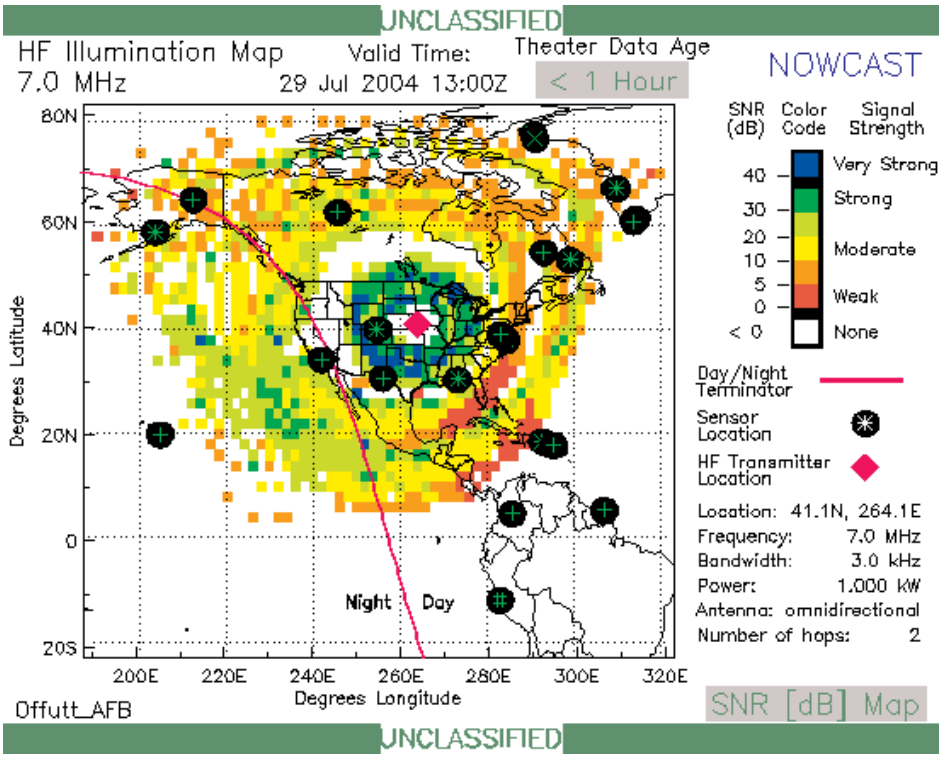

Figure 3-DOD-9. HF Illumination Map (visualized by HQ AFWA).

embedded at the right echelons with decision-makers, to integrate accurate, relevant, and consistent weather and weather impacts information into decision-making processes. Since timeliness is critical to effective integration; AFW operations rely on robust, assured communications for dissemination.

AFWA receives alphanumeric weather data, parses it according to data type, eliminates duplicate reports from different sources, and creates specially tailored bulletins. Some of these bulletins are sent to the large processing centers to provide the input data for global, regional, and fine-scale forecast models. Other bulletins are redistributed to end-users over dedicated circuits, NIPRNET, and satellite broadcast facilities.

High-speed communications between large DOD and civilian processing centers facilitate sharing of data, high-resolution satellite imagery, and output from numerical weather prediction models. Additional circuits provide a subset of these data to OWSs.

Forecaster-developed products and gridded data sets are distributed from AFWA via the Weather Product Management and Distribution System to base/post-level weather forces around the globe using the DOD's Non-Secure Internet Protocol Router Network (NIPRNET) and Secure Internet Protocol Router Network (SIPRNET). Alphanumeric data, including surface, upper-air, space weather, and pilot reports, are also collected and distributed via the Automated Weather Network (AWN), Very Small Aperture Terminal (VSAT) satellite communications system, and the NIPRNET. The AWN, consisting of data collection, message creation, and dissemination software, is a global communications network used for alphanumeric terrestrial and space weather data. The AWN supports DOD as well as federal and foreign meteorological, space, and aviation centers.

AFW operates a website on the NIPRNET known as the Joint Air Force-Army Weather Information Network (JAAWIN). JAAWIN provides worldwide access to numerical model forecasts, satellite imagery, forecaster-in-the-loop (FITL) products, and text bulletins, and includes links to all OWS websites. Additional products are available to classified users via JAAWIN-Secret (JAAWIN-S) and JAAWIN-Sensitive Compartmented Information (JAAWIN-SCI).

Joint Weather Impacts System (JWIS) offers another means of making tailored weather information available to DOD users. JWIS provides a link to weather information from both Air Force and Navy sources for exploitation by command and control systems and applications. AFW successfully demonstrated a JWIS-based machine-to-machine (M2M) weather information transfer to command and control applications during Joint Expeditionary Force Experiment 2004.

Although IT continues to enhance the integration of weather and weather impact information into decision-making processes, well-trained weather professionals are still essential. Designated AFW personnel serve on the staffs of operational Air Force, Army, and Joint force units worldwide. In this capacity, they identify weather-sensitive areas of the operation and provide expert advice to help mitigate weather impacts on personnel, platforms. weapons and weapons systems, and tactics. The ultimate goal is to identify opportunities for an asymmetric advantage over our foes, i.e., when enemy force capabilities are more severely degraded by weather than those of friendly forces.

For Air Force operations, these weather professionals are normally assigned to a flight under an operations support squadron in a flying wing; however, individuals from the weather flight are integrated into flying squadron mission planning and execution processes. In this capacity, they infuse critical weather information at key points in the decision cycle to help aircrews maximize wartime capabilities, enhance flight safety, and opti-

mize training effectiveness. Weather experts are also assigned to weather specialty teams (WST) in air and space operations centers (AOCs). This cross-cutting team integrates all-source actionable environmental information at key decision points of air and space operations planning, execution, and assessment. Armed with this information, decision-makers can balance operational risks against mission need to optimize timing, tactics, target and weapons selection, and other factors affecting air and space operations. Finally, AFW experts are integrated into a variety of other unique mission areas, such as space launch support and research, development, test, and evaluation (RDTE) activities. In each capacity, these specialists enable the supported organization to minimize or alleviate weather impacts to the mission. For instance, to avoid potentially devastating storms, space launch weather personnel may advise decision-makers to adjust launch timing, while RDTE weather personnel may identify potential weather sensitivities to system developers to ensure a safe, effective design.

Likewise, Army weather requirements are incorporated into AFW's overall mission concept. AFW forces are integrated with Army intelligence staffs, and the Army trains and educates Air Force personnel on Army organizations, concepts of operations, and the weather sensitivities. AFW forces are currently habitually aligned with echelons above corps, corps, divisions, separate brigades, aviation brigades, armored cavalry regiments, ranger regiments, and special forces groups (as well as subordinate battalions deployed at forward operating bases). Over the next few years, AFW support to the Army will undergo significant transformation as the Army transitions from a division-centric force based on large standing organizations to a brigade-centric force based on smaller, modular organizations.

RESEARCH INITIATIVES

The overarching objective of the Air Force meteorological and space environmental research and development (R&D) program is to provide capability designers, operational weather personnel, and weather information users with the technology and tools to gain and maintain the advantage over a potential adversary. Documented R&D requirements in the atmospheric sciences are articulated in the AFW Mission Support Plan and in the Mission Area Plans of the Air Force major commands. Space environment R&D is targeted to meet the DOD's space weather requirements as summarized in the National Security Space Architect's Space Weather Architecture Study as well as the National Space Weather Program Implementation Plan, Second Edition. AFW also strives toward improvements through cooperative research and development agreements with for-profit companies. AFW has begun efforts to integrate the Utah State University Global Assimilation of Ionospheric Measurements (GAIM) model. The initial operational capability based on GAIM is planned for 2006.

In meteorological R&D, the Air Force is improving cloud depiction and forecasting (CDF) techniques by doubling the resolution, integrating geosynchronous METSATs into the cloud analysis, using a new cloud interpretation scheme, and blending numerical weather prediction with forecast cloud advection techniques. The Air Force has transitioned key advances in tactical decision aids into operations, permitting improved forecasting of electro-optical system performance and generation of cloud and target scene visualizations for training, system development, and mission rehearsal. In addition to internal efforts, AFW will continue to rely on collaboration and leveraging of efforts with other federal meteorological agencies, research labs, and universities to further improve CDF system performance and meet other research needs.

Mesoscale Modeling for Air Force and Army Operations

Efforts have continued for combining the Land Surface Model (LSM) and MM5 for use by Air Force and Army operations. The LSM analyzes the current state of the land surface to provide information to both DOD and civilian agencies, and through coupling with MM5, will improve forecasting performance in the low levels of the atmosphere. This allows AFW to provide better forecasts for low-level aircraft operations, the dispersion of aerosol contaminants, and the employment of precision-guided munitions. It also allows for assessment of trafficability for ground forces. The advances achieved in the LSM are also being carried over into Weather Research and Forecast (WRF) model development. WRF, the next generation community model expected to replace MM5, is another area of AFWA participation in research. AFWA is closely collaborating with the National Center for Atmospheric Research (NCAR), NOAA's NCEP, NOAA's Forecast Systems Laboratory (FSL), the University of Oklahoma's Center for the Analysis and Prediction of Storms, and others in WRF development. AFWA is preparing to initially implement WRF operationally in 2005 and will continue with sponsorship and funding of development at NCAR and FSL, test and evaluation of real-time runs of the WRF prototype, and will lead the LSM Working Group while participating in others.

Through a joint Air Force-Navy effort, AFWA and FNMOC were awarded a $3 million grant from the DOD High Performance Computing Modernization Office in 2004 to establish an operational test and evaluation center for the WRF modeling framework. Additionally, each organization gained status as a DOD High Performance Computing Distributed Center.

The WRF Operational Test Center (OTC) will greatly enhance DOD's ability to efficiently incorporate state-of-the-science modeling technologies into operations. The end result will be never-before-seen predictive accuracy of fine-scale weather features crucial to DOD operations. A cutting-edge IBM supercomputer suite, split into two identical subsystems, was installed at each weather center. The distributed WRF OTC subsystems will be virtually integrated using high-speed communications networks, allowing operational simulations with real-time weather data from each center. After rigorous test and evaluation, the specialized WRF configurations that perform optimally for DOD and Service-unique mission needs will be implemented at AFWA and FNMOC.

Atmospheric Optical Turbulence

Electro-optical (EO) systems are adversely affected by optical distortions caused by thermal or refractive turbulence. As the sophistication of current and next-generation military systems grows, the requirement for more detailed knowledge of fine-scale (meters or less) atmospheric behavior also grows. The Airborne Laser (ABL) program is one such capability whose performance is highly dependent on the variations of the meteorological conditions that produce optical turbulence. The Air Force program in atmospheric optical turbulence measurements and modeling seeks to address these needs. Researchers used a balloon-borne turbulence sensor mated to a standard radiosonde to obtain measurements, producing data and empirical models that are the basis for ABL system specification. Balloon-borne measurements were made in conjunction with airborne stellar scintillometer measurements to understand the relation between atmospheric structure and path-integrated optical effects. The turbulent scalar spectrum was also sampled using balloon-borne high-bandwidth sensors. As part of an international program, aircraft measurements of temperature and velocity turbulence have been made in different locales worldwide. Horizontal measurements by the aircraft augment the vertical profiling by balloons to assist in the development of the detailed knowledge required to support new EO systems.

United States Weather Research Program (USWRP)

USWRP's mission is to accelerate forecast improvements for high-impact weather phenomena and to facilitate full use of advanced weather information. AFW first entered into discussions with USWRP in 2001 to explore expanded participation in the program. The program currently focuses on land-falling hurricanes, heavy precipitation, and socio-economic impacts. AFW is eager to leverage future efforts in the areas of observing, assimilation strategies for data-sparse regions, and urban forecasting to increase warfighters' abilities to anticipate and exploit the weather. AFW is already committed to the USWRP-affiliated community development of the WRF model and will continue its USWRP involvement during the coming fiscal year.

University Partnering for Operational Support (UPOS)

AFW continued to collaborate through the UPOS program with Johns Hopkins University Applied Physics Laboratory, the University of Alaska at Fairbanks Geophysical Institute, and ARL. UPOS provides a link between university research and the DOD operational community and is currently focused on near-term forecasts of ground, tropospheric, ionospheric, magnetospheric, and solar weather. The goals of UPOS are to provide an alternate path for rapid transition of the best-applied research ideas to the warfighter and to raise awareness of DOD operational needs within the academic community. The partnership delivers prototype operational products to Air Force and Army sponsors. The UPOS Steering Committee, which includes the Air Force Director of Weather, meets semiannually to review progress and approve new projects. UPOS includes warfighter exercise support to demonstrate utility of products through web-based, non-operational access as well as collecting direct user feedback for faster updates of the prototype systems. Some examples of UPOS tropospheric weather work include fine-scale polar numerical weather prediction, operational volcanic plume forecasting, and electromagnetic propagation forecast maps generated from MM5 output. Examples of space science work include high frequency radar and communication propagation to predict the area a transmitter can illuminate, forecasting coronal mass ejections, and improving determination of solar events that will cause militarily significant space weather effects on and near Earth.

Air Force Research Laboratory (AFRL)

In other space weather research, AFRL programs focus on ionospheric impacts to radio frequency systems, space particle specification and forecasts, solar disturbance prediction, and neutral density effects on Low-Earth Orbit (LEO) spacecraft. Working closely with the DMSP System Program Office (SPO) at the Space and Missile Systems Center (SMC) under a Memorandum of Agreement, AFRL supports the development and upgrading of operational space weather sensors, models, and software products to include: space environment sensors on the DMSP spacecraft; state-of-the-art ground-based scintillation detectors; total electron content sensors; DISS; SEON; and the Operationalized Space Environment Network Display suite of web-based products. AFRL also conducts user-supported R&D for NPOESS, the Defense Modeling and Simulation Office (DMSO), the National Reconnaissance Office (NRO), the Ballistic Missile Defense

Office (BMDO), the DOD High Performance Computing Modernization Office, and NASA.

In addition to the AFRL research portfolio, AFW collaborates with others in the space weather community to develop new techniques, models, and systems for transition to operational applications. These include the Community Coordinated Modeling Center (CCMC), the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC), and the previously mentioned UPOS.

In conclusion, through a continuous process of review and definition, the Air Force documents its requirements for research aimed ultimately at providing timely, accurate, relevant, and consistent weather information to the warfighter today and in the future. In meteorological R&D, AFW is committed to continued development of the WRF model and collaboration with others to the benefit of the warfighter and the nation. Space weather research will continue with a strong program in 2006 at the AFRL, as well as in leveraged programs such as UPOS, to facilitate the transition of required capabilities to operational use at minimum expense.

METEOROLOGICAL SERVICES

The United States Navy has the unique military requirement to assess meteorological and oceanographic (METOC) impacts on naval, joint, and combined operations. METOC support begins by measuring the battlespace physical environment and culminates with safe, effective weapons systems and sensor employment. Environmental support is global, and historically focuses on areas outside of the contiguous 48 states, but the emphasis is on wherever the Fleet goes and includes force protection within the coastal waters of the U.S. Developing METOC forecasts and determining potential effects on platform, sensor and weapons systems require:

- collection of METOC data through tactical and dedicated sensors (including satellites);
- fusion and analysis of atmospheric and oceanographic data; and
- integration of meteorological and oceanographic information in tactical decision aids and mission planning systems.

The Office of the Oceanographer of the Navy, Chief of Naval Operations (CNO) N7C, is an Echelon I Staff that reports to the Deputy CNO for Warfare Requirements and Programs (N6/N7). The Commander, Naval Meteorology and Oceanography Command, is an Echelon III Command that reports to the Commander, Fleet Forces Command (CFFC). While operational requirements are coordinated through CFFC, it is the Chief of Naval Operations, through the Oceanographer of the Navy, who continues to sponsor operational Navy METOC support services and related research and development (R&D). The Navy METOC organization provides meteorological support services for Navy and joint forces, meteorological products to the uniformed services and other Government agencies, and oceanographic support to all elements of DOD.

The United States Navy is building upon its strengths, thus enabling an asymmetric war fighting advantage over its adversaries. One of these strengths is the Navy's ability to apply Meteorology and Oceanography to its battle problems and challenges in order to leverage the environment for an advantage. The Naval Meteorology and Oceanography Command provides that advantage for the Navy through the application of its scientific disciplines: oceanography, meteorology, geo-spatial information and services and precise time and astrometry.

In 2004, the Naval Meteorology and Oceanography Command aligned internally from a geo-centric to knowledge-centric organization designed to directly and measurably enhance warfighting capabilities.

The Command is aligned along the following warfare and warfare support areas:

- Antisubmarine Warfare (ASW)
- Naval Special Warfare
- Mine Warfare (MIW)
- Intelligence, Surveillance and Reconnaissance (ISR)
- Fleet Operations (Strike Warfare and Expeditionary Warfare)
- Navigation
- Precise Time and Astrometry
- Maritime Operations
- Aviation Operations

In the new Command structure, the Commander, Naval Meteorology and Oceanography Command now directly measures, applies and adjusts resources across the enterprise toward specific warfighting needs. Collection and production are centralized at the Fleet Numerical Meteorology and Oceanography Center (FNMOC) in Monterey, California, and the Naval Oceanographic Office (NAVOCEANO), located at Stennis Space Center, Mississippi. Service delivery is uniformed, minimized, decentralized and located at the Naval Warfighting Command nodes. The Command's personnel are located at its headquarters at Stennis Space Center near Bay St. Louis, Mississippi, and at several field activities located around the world.

Warfare centers, laboratories, and systems commands, through sponsorship by the Chief of Naval Research and the Oceanographer of the Navy, conduct METOC research and development. To ensure that all research and development supported by the Oceanographer is in direct support of the Naval Mission as established by formal Navy Doctrine, the Oceanographer has developed and implemented a comprehensive framework to transition research to operations. The Naval Research Laboratory (NRL) and the Program Executive Office (PEO), C4I and Space (PMW 180) are the primary activities that manage naval METOC research and transition to operations, and are supplemented by various universities, industry partners, and organizations under Navy contract. NRL detachments are collocated with the Fleet Numerical Meteorology and Oceanography Center in Monterey, California and with the Naval Oceanographic Office at Stennis Space Center, Mississippi. The PEO C4I and Space Program Office (PMW-180) is the Navy's program manager for METOC system development and acquisition.

FLEET NUMERICAL METEOROLOGY AND OCEANOGRAPHY CENTER

The U.S. Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC; see https://www.fnmoc.navy.mil/) plays a significant role in the National capability for operational weather and ocean prediction through its operation of sophisticated global and regional meteorological and oceanographic models, extending from the top of the atmosphere to the bottom of the ocean. Through close collabora-

Figure 3-DOD-10. At sea with USS PRINCETON (CG 59) -- Waves crash over the bow of the guided missile cruiser while receiving nearly 100,000 gallons of JP-5 jet fuel from aboard the aircraft carrier USS NIMITZ (CVN 68) during an underway replenishment (UNREP) off the California coast.

tion with the Naval Oceanographic Office (NAVOCEANO), FNMOC is a key component in the Navy's operational weather and ocean prediction program. This program provides information that helps give Naval forces an asymmetric advantage in speed, access and persistence in any combat operation for which they may be called upon. Users of FNMOC's products include all branches of the Department of Defense (DOD), the intelligence community, and other government organizations such as the National Weather Service, private companies, a number of colleges and universities, and the general public.

FNMOC is well known for its long and productive history of implementing, evaluating, operating, maintaining and improving complex Numerical Weather Prediction (NWP) models specifically to meet the requirements of the U.S. Navy. These requirements include the need for a particularly accurate representation of coastal meteorology and the air-sea heat fluxes and wind stresses required to drive the Navy's ocean models. In support of this need, FNMOC acquires and processes over six million observations per day-creating one of the world's most comprehensive real-time databases of meteorological and oceanographic observations-for real-time fusion and assimilation into its models. In addition, FNMOC is designated as the DOD center for global Numerical Weather Prediction. FNMOC uniquely satisfies the military's requirement for an operational global NWP capability based on software certified to DOD information assurance standards and operated in a secure classified environment protected from outside intrusion by DOD certified firewalls. This requirement is driven by the importance of weather and ocean conditions on modern military operations, the need to utilize classified weather observations to guarantee the very best weather and ocean predictions in theaters of conflict, and the imperative to produce and disseminate weather and ocean products to military decision makers without fear of interruption or compromise as a result of cyber terrorists or cyber warfare.

FNMOC employs four primary models, the Navy Operational Global Atmospheric Prediction System (NOGAPS), the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS), the Geophysical Fluid Dynamics - Navy (GFDN) model, and the Wave Watch III model (WW3), along with a number of specialized models and related applications. NOGAPS is a hydrostatic, global spectral model that drives nearly all other FNMOC models and applications in some fashion, and forms the basis for the FNMOC global Ensemble Forecast System (EFS). COAMPS is a high-resolution, non-hydrostatic regional model, multiply nested within NOGAPS, which has proven to be particularly valuable for forecasting weather and ocean conditions in highly complex coastal areas. GFDN is a moving-nest tropical cyclone (TC) model, nested within NOGAPS that is used to forecast TC tracks globally. WW3 is a spectral ocean wave model that is employed both globally (driven by NOGAPS) and regionally (driven by COAMPS) in support of a wide variety of naval operations. Other models support and supplement the main models with predictions of ocean thermal structure, ocean currents and other data. All of the models are configured, scheduled and operated under the central control of FNMOC Operations. COAMPS, however, can also be configured, scheduled and operated remotely by users in the field as an on-demand modeling service. This is done over the Web via the FNMOC Centralized Atmospheric Analysis and Prediction System (CAAPS). In general, FNMOC strives to treat the air-ocean environment as a fully integrated system, from the top of the atmosphere to the bottom of the ocean, placing special emphasis on the air-ocean interface.

FNMOC's complex and robust operational prediction capability is designed to deliver, in conjunction with NAVOCEANO, twenty-four hour

year round support organized along the following Business Lines:

- Anti-Submarine Warfare
- Naval Special Warfare
- Mine Warfare
- Intelligence, Surveillance and Reconnaissance
- Fleet Operations (including Strike Warfare and Expeditionary Warfare)
- Navigation (including support for Fleet Ballistic Missile Submarines)
- Aviation Safety
- Maritime Safety

For example, some FNMOC products consist of detailed forecasts of wind stresses and heat fluxes to drive very high-resolution ocean models at NAVOCEANO that provide ocean thermal structure and currents in support of anti-submarine and mine warfare operations, or near-shore wind, sea and surf forecasts that directly support Fleet Operations through ship-to-objective maneuver. In many cases, the outputs of the FNMOC models feed directly into applications models, tactical decision aids and other products that provide direct support to various weather-sensitive activities associated with the Business Lines identified above. These include optimum path aircraft routing, optimum track ship routing, issuance of high-winds and high-seas warnings, hurricane/typhoon sortie decisions, covert ingress/egress of Special Operations Forces, ballistic missile targeting, cruise missile launch and targeting, radar performance prediction in support of ship self defense, naval gunfire operations, understanding the threats posed by airborne nuclear/biological/chemical agents, search-and-rescue at sea, and many other activities.

FNMOC also provides a wide-range of meteorological and oceanographic observations and satellite imagery to complement its models and applications products. These include on-demand extracts from its global observational database, a full range of Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I) products, ERS and QuikScat scatterometer wind products, a comprehensive view of tropical cyclones via the FNMOC TC Web Page, and various experimental satellite products fielded for evaluation in conjunction with the Naval Research Lab (e.g., satellite imagery that enhances the visualization of airborne sand and dust). FNMOC also hosts the U.S. Global Ocean Data Assimilation Experiment (GODAE) Monterey Data Server in support of the GODAE. This system serves as a one-stop shop for meteorological and oceanographic data and model products required to support global ocean modeling R&D. It also functions as one of two Argo Global Data Assembly Centers (GDACs), hosting the complete collection of quality-controlled Argo temperature/salinity profiling float data.

Many of FNMOC's products are distributed to users over the Web via the PC-based METCAST system, and subsequently displayed and manipulated on the user's PC with the Joint METOC Viewer (JMV) software. This includes all standard meteorological and oceanographic fields, synoptic observations, and satellite imagery. For those who require only graphical display of model-predicted meteorological or oceanographic fields, FNMOC provides a Web-based capability called MyWxMap (i.e., "My Weather Map"). MyWxMap, requiring only a Web browser for access, allows the user to select and quickly display predicted meteorological and oceanographic fields for any user-defined geographical area.

All of FNMOC's production capabilities are fielded on a collection of computer hardware and software constituting a DOD Major Automated Information System and designated as the Primary Oceanographic Prediction System (POPS). POPS is organized into two subsystems: the Analysis and Modeling Subsystem (AMS) and the Applications, Transactions, and Observations Subsystem (ATOS). AMS is a cluster of SGI and IBM supercomputers on which the major NWP models run. ATOS is a large suite of IBM Linux clusters that ingests, decodes and quality-controls data; does satellite data processing; hosts many of the applications models and products mentioned above; and supports data distribution via a services oriented architecture and Web portal. Note that FNMOC also hosts two DOD High Performance Computing Modernization Program (HPCMP) Distributed Centers, which are integrated closely with POPS.

In addition to its primary role of focused support to the warfighter, FNMOC also plays a key role in the U.S. national program for weather prediction. In this regard, FNMOC's tropical cyclone track predictions, widely recognized as among the best in the world, have proven to be especially valuable, with the National Hurricane Center (NHC) relying on them heavily. FNMOC also provides an important and physically separate backup for some of the models run at the National Weather Service's National Centers for Environmental Prediction (NCEP). In addition, FNMOC serves as the Alternate Joint Typhoon Warning Center (AJTWC), providing the backup for the JTWC located in Pearl Harbor, Hawaii. And finally, the subset of FNMOC products made available to the general public via the Internet is used widely by both commercial and recreational marine interests.

FNMOC benefits greatly from collocation with its supporting R&D activity, the Marine Meteorology Division of the Naval Research Laboratory (NRL/MRY). NRL/MRY is a world-class research organization, with focus on weather-related support for the warfighter. FNMOC and NRL/MRY share space, data, software and com-

puter systems, and together with the nearby Naval Postgraduate School represent one of the largest concentrations of weather-related intellectual capital in the nation. Collocation and close cooperation between research and operations, such as exists between NRL/MRY and FNMOC, is the optimum arrangement for transitioning R&D quickly and cost-effectively into new and improved operational weather prediction capabilities. In addition, both FNMOC and NRL/MRY are working to leverage strategic partnerships and community modeling efforts such as the Weather Research and Forecasting (WRF) and Earth Systems Modeling Framework (ESMF) programs.

NAVAL OCEANOGRAPHIC OFFICE

Since atmospheric conditions are inherently coupled to oceanographic conditions, the Navy's program in meteorology is closely linked with oceanography, which is the focus of the Naval Oceanographic Office (NAVOCEANO), Stennis Space Center, Mississippi. NAVOCEANO's primary responsibilities include the collection, processing, and distribution of oceanographic, hydrographic, and other geophysical data and products. NAVOCEANO runs and disseminates products from the world's first operational global ocean model - Naval Research Laboratory (NRL) Layered Ocean Model (NLOM) as well as a number of regional and coastal circulation and wave models. NAVOCEANO also runs the Polar Ice Prediction System (PIPS) ice model.

A key ingredient to ocean model performance is real-time data for assimilation and evaluation. NAVOCEANO is the Navy's primary processing facility for NOAA polar-orbiting satellite data and is nationally recognized for satellite-derived sea-surface temperature and satellite altimeter-derived sea-surface topography and wave height. NAVOCEANO's global sea surface temperature data are critically important to successfully running NOGAPS and COAMPS. Additionally, NAVOCEANO houses a DOD Major Shared Resource Center, enabling transition of the latest research and development models on the most modern scaleable, supercomputing architecture and facilitating transition from R&D to operational use. The NAVOCEANO web site for information is https://www.navo.navy.mil.

NAVAL ICE CENTER

The Naval Ice Center (NAVICECEN), located in Suitland, MD, provides tailored ice forecasts and analyses to DOD. The Navy (through NAVICECEN), NOAA, and the U.S. Coast Guard, jointly operate the National Ice Center (NIC). The NIC provides ice analyses and forecasts for the Arctic and Antarctic regions, coastal U.S. waters, and the Great Lakes to civilian and military activities.

METOC SUPPORT TO THE NAVAL WARFIGHTING AREAS

ANTI-SUBMARINE WARFARE (ASW)

The Naval Meteorology and Oceanography Command provides Anti-Submarine Warfare commanders with critical environmental knowledge that defines the battlespace and helps warfighter planning and operations. The need for this real-time infusion of environmental knowledge is especially important in modern warfighting as ASW is increasingly likely to occur in littoral regions where conditions can change rapidly and dramatically.

Contributions to ASW consist of an unequaled expertise in oceanography and meteorology, a variety of high-tech sensing tools, powerful supercomputers and highly skilled personnel all working together to form a flexible network of warfighter support.

Characterizing the Battlespace. There are several environmental factors that together define the ASW battlespace and help warfighters determine the right platform, weapons, targets, settings, tactics and timing necessary for maximum effectiveness. Naval oceanographers monitor and analyze these variables and provide data directly to decision-makers. These environmental factors include:

- acoustics and ambient noise;
- bathymetry;
- temperature and salinity;
- bottom-mapping;
- tides and currents.

The Naval Meteorology and

Figure 3-DOD-11. Navy pilot discusses current weather conditions displayed on large plasma screens with the forecaster prior to take-off.

Oceanography Command is effectively aligned to provide skills and resources for ASW mission success. Important supporting assets are:

• Skilled Personnel Deployed Worldwide. Military and civilian personnel are deployed worldwide to provide a flexible support team to warfighters. Littoral Warfare Teams combine on-scene and reach back personnel to collect, consolidate and interpret data from a variety of sources and sensors for delivery to decision-makers.

• High-Performance Computing. With the Major Shared Resource Center, advanced models, high bandwidth data transfers and supporting databases information can be processed and delivered quickly to warfighters.

• Advanced Sensing Technology. Gliders, Autonomous Unmanned Vehicles (AUVs), Underwater Unmanned Vehicles (UUVs) and towed sensors define the battlespace for ASW warfighters and aid planning and operations. The unmanned sensors can improve littoral surveying, especially in denied areas, while providing real-time data over extended periods.

• Comprehensive Data Collection. Data that supports warfighting is collected from multiple sources including: Fleet Survey Teams on T-AGS 60 ships and Hydrographic Survey Launches (HSLs), buoys, satellites, remotely operated unmanned sensors and other sources.

• ASW-Specific Training. Naval oceanographers are trained on tactical oceanography as it relates to ASW.

NAVAL SPECIAL WARFARE

The Naval Meteorology and Oceanography Command actively contributes to Naval Special Warfare success by providing a broad array of environmental knowledge, giving warfighters tactical advantages in the forward battlespace. Environmental expertise in the highly-dynamic littoral and riverine environments are especially crucial to Special Forces who are often leading the fight in the global war on terrorism in remote regions of the world.

Naval Special Forces are playing a prominent role in military operations in Afghanistan and Iraq. The environmental information and expertise provided by Naval Oceanography is an integral part of the mission planning and execution process. Near real time intelligence allows NSW forces to use the environment for optimum effectiveness - enabling them to accomplish missions safer and more efficiently while providing critical go/no go recommendations.

Environmental Factors.

Because Naval Special Forces often operate in near-shore, highly-dynamic areas, there are numerous environmental factors that impact mission accomplishment. These include: surf conditions; tides; currents; sea and swell heights; bathymetry; sea temperature; visibility; sediment characteristics; weather conditions; hazardous marine life; and lunar illumination.

Resources and Skills.

Naval Meteorology and Oceanography Command resources and skills that contribute to Naval Special Warfare include:

• Data collection from a variety of sources and sensors, both on-scene and remote.

• Computing power of the Major Shared Resource Center and high-speed transmissions that deliver complex models and data to warfighters real-time.

• Tactical decision aids, satellite imagery with overlays, global and tactical level models and riverine models to improve decision-making of warfighting commanders.

• Global to tactical scale predictions of tide, surf, and current conditions that characterize the battlespace.

• Personnel with scientific expertise and data and imagery analysis skills providing direct support to the NSW Mission Support Center and NSW commanders.

• Reach back cells that work with on scene personnel to refine data, provide expert analysis and deliver products to warfighters.

• AUVs, UUVs, towed sensors and gliders that can collect data in hard to access and denied areas providing intelligence to NSW warfighters over extended periods of time.

• Versatile survey ships, HSLs, aircraft, buoys and other data collection platforms deployable around the world.

MINE WARFARE

Environmental conditions strongly impact mining and mine countermeasures operations. All aspects of mine warfare, from mine laying to mine hunting and mine sweeping operations are significantly affected by environmental conditions, especially in coastal regions where temporal and spatial variability of the environment are the greatest. Knowledge of the littoral battlespace is necessary for successful mission planning of mine warfare sensors and timely execution of tactics to support mining operations. The Naval Meteorology and Oceanography Command provides ongoing support for the Navy's Mine Warfare forces to neutralize threats and to allow for assured access of maritime assets in these strategic regions in interests.

The Naval Oceanographic Office's (NAVOCEANO) bottom mapping and imaging information, oceanographic models, weather forecasts, warfare support teams and mine warfare environmental databases play a vital role in eliminating mine hazards. During Operation Iraqi Freedom environmental data collected from mine countermeasures vessels, survey ships, tactical aircraft, buoys and satellites were critical in developing realistic mine clearance timelines which expedited the clearance of waterways leading to Iraqi ports.

Mine Warfare efforts are a primary focus of the Meteorology and Oceanography Command. Key aspects of this command-wide focus are:

• Oceanographic Expertise. NAVOCEANO scientists are continually developing advanced methods to provide near real-time engagement to the warfighter. NAVOCEANO's scientific expertise, modeling and image analysis tools, on-scene participation and the computing power of the Major Shared Resource Center provide a major contribution to in-theater mine warfare planning and operations.

• Mobile Mine Warfare Teams (MMTs). Specially trained environmental teams from Oceanography community are deployed on vessels in-theater to provide analysis of the meteorological, oceanographic and geologic conditions in the battlespace. They also contribute weather forecasts, interpret bottom-mapping side scan sonar imagery, analyze water properties, bathymetry, tides and currents and provide timely and expert advice to Mine Warfare commanders on the optimization of mine warfare sensors and weapon systems.

Important Oceanographic contributions to Mine Warfare include:

• Mine Warfare Environmental Decision Aids Library (MEDAL). NAVOCEANO's databases are an integral component to the mine warfare tactical decision aid, MEDAL. These databases incorporate in-situ data from the battlespace with existing information to help mine warfare forces effectively plan and conduct operations.

• Weather Forecasts. Oceanography community personnel provide near real-time weather forecasts to assist mine warfare commanders determine mine countermeasure methods to employ and to provide early warning of severe weather that could affect the performance of Naval personnel and assets.

• Bottom Mapping. Oceanography personnel interpret acoustic imagery acquired from tactical units and Underwater Unmanned Vehicles (UUVs) in-theater and/or transmitted to NAVOCEANO where it is assimilated with historic data to provide near real-time description of the seafloor, including seafloor characteristics, water depths, and image mosaics of the seafloor. These data assist mine warfare units determine mine clearance rates and distinguish between mines, other man-made objects and natural features.

• Tides, Currents, Optics and Salinity. Oceanographic experts from the MMTs supply warfighters with accurate tidal, current and salinity data during mine countermeasure operations. This information is crucial in determining deployment windows for UUVs, man/mammal diving operations and for determining sensor performance.

INTELLIGENCE, SURVEILLANCE AND RECONNAISSANCE (ISR)

The Naval Meteorology and Oceanography Command collects and disseminates environmental data providing direct support to the Intelligence Community and warfighters, such as special operations forces and expeditionary strike groups.

The command's data collection capabilities are far-reaching - collection platforms, such as ships, buoys, satellites, gliders, UAVs and AUVs can retrieve ISR data worldwide, even in remote and denied areas.

Naval Meteorology and Oceanography Command contributions to the Intelligence, Surveillance and Reconnaissance Community:

• Meso- and micro-scale oceanography and meteorology.

• Long-range forecasting of oceanographic conditions critical to the Intelligence Community.

• Collection and analysis of environmental data that is an important part of Intelligence Preparation of the Battlespace (IPB).

• Target Area METOC (TAM) analysis.

• Better characterization of littoral ocean areas and special operation and expeditionary warfare support through Surf Eagle, which processes intelligence data to produce materials tailored for the warfighter.

• Comprehensive network of sensors for collecting data from all areas of the world - from the oceans to atmosphere. Collection platforms include AUVs, UUVs, towed sensors, gliders, survey ships, launches, buoys and satellites.

• Computing power, models and high-quality imagery for integration and real-time dissemination of ISR to Intelligence Community and warfighter commands.

• Personnel deployed in-theater or remotely to collect, process, analyze and interpret intelligence data in coordination with Intelligence Community.

Figure 3-DOD-12. A Landing Craft Utility (LCU) approaches the well deck of the amphibious assault ship USS TARAWA (LHA 1) while the Chilean Leander-class frigate CS LYNCH (PFG 07) operates in the waters astern of the ship during the Rim of the Pacific (RIMPAC) naval exercise last year.

FLEET OPERATIONS

The Naval Meteorology and Oceanography Command is actively engaged with Fleet forces to provide valuable environmental knowledge to aid warfighter decision-making. Skilled and combat-certified personnel are integrated with the Fleet, where

they provide in situ observations, run tactical decision aids and interpret environmental data to provide decision support to fleet commanders.

The onboard personnel work with reachback cells, manned with subject matter experts, to analyze and forecast environmental conditions from launch point to target to determine optimum fleet maneuvers, ingress and egress routes, amphibious landing points and times, flight operations, weapons load outs and target selection.

Major contributions to Fleet Operations, Expeditionary Warfare and Strike Warfare include:

• Collecting, processing, interpreting and delivering environmental data coming from multiple sources.

• Characterizing the battlespace from the atmosphere, to the deep oceans, to the shore.

• Personnel that are warfare-qualified meteorology and oceanography specialists deployed on vessels to support planning and operations.

• Reachback teams that work with onboard personnel to refine data, develop models, conduct forecast analyses and deliver high-quality information to fleet commands.

• Supercomputing capabilities, satellites, and high-bandwidth data transfers that quickly process and deliver information to key decision-makers.

• Battlespace preparation in highly variable littoral regions where factors such as tides, surf, currents and obstructions can have significant affects on fleet objectives.

• Tactical decision aids for optimizing impacts of the environment on specific platforms, sensors and weapons.

• Decision aid libraries, targeting models, radar models and databases.

• Support for Ship to Objective Maneuvers (STOM).

Each Strike Group will retain a highly trained cadre of meteorologists and oceanographers who forecast for the 4.5 acres of US sovereign territory that moves freely in any ocean, at anytime, around the globe; in addition to flight deck weather, they forecast the target area METOC which varies greatly considering the tremendous reach of Naval Aviation along the world's dynamic coastlines.

NAVIGATION

The Naval Oceanography Program is effectively aligned to provide comprehensive oceanographic and navigation knowledge to warfighters. On-scene and reach back personnel, high-tech surveying capabilities, complex models and high-speed data transmissions form a flexible network of near real-time support for navigation. Whether it's assisting mine detection and clearance, ensuring safe passage for submarines and surface ships, or providing special operations forces with advantages in the forward battlespace, Navy Oceanography is engaged to efficiently collect, understand, and apply navigation information to effect advantageous outcomes across strategic, operational, and tactical scales of naval warfare.

Key components of Navy Oceanography's success are:

• Knowledgeable Personnel. Littoral Survey Teams, comprised of military and civilian oceanographers, are deployed globally aboard T-AGS 60 ships and various other platforms to provide quick-response navigation-quality surveys. These teams work in coordination with reach back cells and embedded personnel to deliver environmental information to decision-makers.

• Airborne LIDAR Bathymetry. Using airborne laser bathymetry, Navy Oceanography can provide navigation-quality charts for large areas of coastline. These rapid-response surveys are important for warfighter planning and operations in littoral regions, especially where knowledge is limited or non-existent. The Navy's airborne charting and mapping system combines hydrographic and topographic data with digital imagery to produce more complete characterizations of littoral regions for improved coastal navigation.

• Autonomous Underwater Vehicles (AUVs). The Subsurface Autonomous Mapping System (SAMS) and Seahorse are Navy Oceanography's two programmable, redirectable, free-swimming AUVs. SAMS can conduct physical oceanographic data collection or side-scan sonar bottom-mapping surveys. It has full ocean depth capabilities and can collect 10-12 hours of side-scan data for 40 nautical miles, or up to 16 hours of oceanographic data over 65 nautical miles. The Seahorse AUV is designed to collect high-quality, precision located environmental data from littoral regions. It is capable of pre-programmed independent operations over 72 hours, covering 300 nautical miles.

• Fleet of Multi-purpose Survey Ships. Navy's fleet of 7 survey ships and hydrographic survey launches are deployed around the world to make in situ observations and work with reach back personnel to provide near-real-time support for tactical navigation.

• Navigation and Oceanographic Products. These include: High-resolution bathymetry; navigation-quality charting (for digital or paper products); bathymetric databases; gravity and bathymetry surveys at sea to support SSBN operations; surveys to locate hazards and determine physical bottom conditions; surveys of harbors and approaches.

PRECISE TIME AND ASTROMETRY

The U.S. Navy and Department of Defense require precise time and astrometry for communications, weapons targeting, and precision navigation. The United States Naval Observatory (USNO) is the sole provider to the defense community of this information, which is vital to mod-

ern warfare. Key support areas are:

• Time. USNO is the official source of time for the Department of Defense and Navy. It determines, maintains, and disseminates precise time and time interval reference values, ensures uniformity, provides timing data for navigation, precise positioning and C3, and maintains the Master Clock. An active research program to develop even more precise clock systems ensures that USNO will be able to continue to meet the most stringent timing requirements.

• Astrometry. USNO is a world-recognized leader in astrometry. The Astrometry Department determines fundamental positions, motions and distances of celestial objects and ascertains the real-time relative positions of these objects to establish reference frames in the sky. Astrometry is required by the Navy and the Department of Defense for navigation systems, precise positioning, and communications.

• Earth Orientation. USNO provides real-time data about the Earth's orientation and rotation, which are necessary for a variety of high-precision applications, both military and civilian. Earth orientation and rotation parameters impact navigation, precise positioning, astronomy, geodesy, communications, and time-keeping.

Impact on warfighter operations:

• Precise timing and Earth orientation parameters are key enablers for precision strike. Accurate and precise parameters are necessary for the Global Positioning System (GPS), which is used for navigation and weapons systems guidance.

• Precise atomic clocks are used as a time standard for satellites and other communications platforms.

• Precise timing is required for communications in network-centric warfare ensuring interoperability of warfighter support systems, such as tactical data links, Global Information Grid (GIG), FORCEnet synchronization, ISR Battle management, and other C4I systems.

• Astrometry is used as reference for guidance systems and to navigate and orient space-based platforms.

The defense, scientific, commercial, and civilian communities use USNO astronomical catalogs and expertise.

AVIATION OPERATIONS

A key task of the Naval Meteorology and Oceanography Command is to support Naval aviation around the world, with a particular emphasis on mission accomplishment and safety of flight. Meteorologists analyze current environmental conditions and computer models to provide forecasts that enable safe flight operations, provide optimum flight routing, and meet tactical objectives 24 hours a day, 7 days a week. These forecasts are essential to protect lives and property of the Navy and Department of Defense and result in mission accomplishment for the "warfighter." An accurate forecast is often the critical factor in mission success. Routine weather conditions such as cloud cover, dust, and precipitation often have major impacts on the type, effectiveness, and delivery tactics for many of today's sophisticated weapons.

Highly trained meteorologists assigned to globally dispersed activities provide:

• Flight Weather Briefings (DD 175-1).

• Horizontal Weather Depictions (HWD)

• Local area and point weather warnings for Navy airfields.

• Terminal Aerodrome Forecasts (TAF) disseminated every 6 hours.

• In-theater analysis, forecasts, advisories for aircraft.

Several of the state of the art systems used include:

• Optimum Path Aircraft Routing System (OPARS). A computerized flight planning system for determining the most fuel-efficient altitude and flight path that saves millions of dollars a year on fuel costs.

Leading Environmental Analysis and Display System (LEADS) and Navy Integrated Tactical Environmental Subsystem (NITES) Aviation Forecasting Systems. Primary display, analysis, and production systems used by our forecasters.

• Automated Surface Observing System (ASOS) and Remote Automated Weather System (RAWS). Primary airfield environmental observing systems.

• Naval Flight Weather Briefer (NFWB). An automated web-based system used to request, produce and disseminate flight weather briefings.

Figure 3-DOD-13. Navy Mobile Environmental Team (MET) Leader experiences a dust storm at sea aboard the USS GUNSTON HALL (LSD 44).

MARITIME OPERATIONS

The Naval Meteorology and Oceanography Command provides timely and accurate weather and ocean products to ensure safe and efficient ship operations. Key components of Maritime Operations mission are ship routing, forecasts and warnings and support for ice operations.

Significant contributions to maritime safety and efficiency include:

• Optimum Track Ship Routing (OTSR). OTSR is an enroute weather forecasting service to support trans-oceanic transits and coastal operations of Navy and naval support ships. Meteorology and oceanography personnel advise Commanding Officers and Ship Masters at sea, providing weather advisories and storm evasion recommendations to avoid hazardous weather. OTSR services also include sortie recommendations for potentially damaging weather conditions in port. Additionally, OTSR provides climatologic outlooks for preliminary transit and mission planning.

• Delivery of tropical cyclone forecasts, warnings and other products. Established by the U.S. Pacific Command and jointly manned with U.S. Air Force personnel, the Joint Typhoon Warning Center (JTWC) located in Pearl Harbor Hawaii is an internationally recognized tropical cyclone forecasting agency.

• Ship weather forecasts (WEAX).

• Aviation weather forecasts for ship-based helicopters (AVWX).

• High wind and seas warnings, special weather advisories and local area warnings.

• Ice analysis and forecasting by the National Ice Center, a joint operation of the Naval Ice Center, U.S. Coast Guard and NOAA.

• Operational Weather Briefs for other Maritime Operations to include Navy and U.S. Coast Guard Search and Rescue (SAR).

• Joint Operational Area Forecasts (JOAF) for Commanders operating in Littoral regions.

UNITED STATES MARINE CORPS (USMC)

The mission of the Marine Corps METOC Service is to provide meteorological, oceanographic, and space environmental information, products, and services required supporting Marine Corps and other military operations. The Marine Corps METOC support infrastructure is designed to readily deploy and operate in austere expeditionary environments. It is capable of providing sustained, comprehensive, and relevant METOC support to all elements of a Marine Air Ground Task Force (MAGTF), as well as bases and stations of the supporting establishment.

Organization

The Deputy Commandant for Aviation, Headquarters United States Marine Corps (Code ASL-37), is the cognizant office for Marine Corps METOC support and requirements. The Marine Corps METOC organization consists of two operational chains-of-command, one for supporting establishment METOC units and the other for the Fleet Marine Force (FMF).

Supporting establishment METOC units are located worldwide at Marine Corp Air Stations (MCAS) and Facilities (MCAF). These activities are manned and equipped to provide direct aviation METOC support and services to host and tenant units at nine major air stations in the continental United States, one in Hawaii, and two in Japan.

Within the FMF, Marines deploy and employ as scalable, tailorable, combined-arms teams known as Marine Air Ground Task Forces. There are three sizes of MAGTFs. From smallest to largest, they are: Marine Expeditionary Unit (MEU), Marine Expeditionary Brigade (MEB), and Marine Expeditionary Force (MEF). Additionally, Special Purpose MAGTFs (SPMAGTFs) may be formed to support operationally unique situations and/or requirements. All MAGTFs, regardless of size, share four organizational elements that vary in size and composition according to the mission: Command Element (CE), Ground Combat Element (GCE), Aviation Combat Element (ACE), and Combat Service Support Element (CSSE).

FMF METOC activities are organized, trained, and equipped to provide tailored support, products, and services to all combat elements of the MAGTF. METOC support is focused towards impacts on Expeditionary Maneuver Warfare (EMW) operations, particularly Operational Maneuver from the Sea (OMFTS). FMF METOC activities are fully interoperable within joint force operations as part of a service or functional component command. When directed to stand-up as part of a Joint Task Force Headquarters (JTF HQ), they are capable of planning, coordinating, and leading joint METOC operations. Marine METOC forces can rapidly transition from pre-crisis state to full operational capability in a distant theater to provide on-scene support to MAGTF, combined, joint, allied, and coalition operations and other military operations as may be directed.

FMF METOC assets are permanently assigned to Marine Expeditionary Force Headquarters (MEF HQ), Intelligence Battalions, Marine Wing Support Groups (MWSGs), and Marine Wing Support Squadrons (MWSSs). There are three Marine Expeditionary Forces strategically positioned for global response. I MEF, based in southern California and III MEF, forward based in Okinawa, mainland Japan, and Hawaii fall under the control of the Commander, Marine Forces Pacific. II MEF, located at bases in North and South Carolina, falls under the command of the Commander, Marine Forces Atlantic. MEF METOC personnel serve as special staff to the Commanding General (CG)

Figure 3-DOD-14. The transportable Marine Corps Meteorological Mobile Facility Replacement (METMF(R)) houses meteorological support equipment for a Marine Air Ground Task Force (MAGTF) established at an expeditionary airfield.

and are under the direction and cognizance of the G-2 (Intelligence) Division.

The three Intelligence Battalions in the Marine Corps are co-located with respective Marine Expeditionary Force Headquarters. These battalions directly support the MEF G-2 and serve as MAGTF intelligence centers during operations. METOC is a vital part of the intelligence estimate and is an essential element that supports the Marine Corps Rapid Response Planning Process. METOC personnel assigned to these commands provide expertise, products, and services that directly support the Intelligence Preparation of the Battlespace (IPB) process by helping intelligence analysts to effectively evaluate, integrate, and synchronize METOC effects for both enemy and friendly courses of action.

Marine Aircraft Wings (MAWs) conduct the complete range of air operations in support of the MEF, to include anti-air warfare, offensive air support, assault support, aerial reconnaissance, electronic warfare, and control of aircraft and missiles. The MAW serves as the principle headquarters for the ACE. Most of the MAGTF's METOC support assets reside within the MAW, specifically at the MWSG and its subordinate MWSSs. These assets are organized, structured, and capable of supporting a variety of MAGTF and ACE-specific operations as defined by the size, scope, and mission requirements. Dedicated METOC support is available for all MAGTF elements from within the MAW/ACE.

METOC Support Capabilities

Meteorological Mobile Facility-Replacement (MetMF(R)) - The highest level of METOC support to the MAGTF and ACE-specific operations is the deployment of the MetMF(R). The MetMF(R) provides a METOC support capability similar to that found in garrison METOC facilities, is normally deployed as part of MWSS to a Forward Operating Base (FOB), and is the only realistic option for large-scale MAGTF operations. Once established ashore, the MWSS may detach small METOC support teams with portable ancillary equipment to a forward base in support of ACE units that are separated from the main airbase. This redeployment also provides the MetMF(R) with a forward data collection capability that significantly enhances METOC situational awareness and overall support efforts to the entire MAGTF. With appropriate service personnel augmentation, the MetMF(R) is also capable of serving as host for an in-theater Joint METOC Forecasting Unit (JMFU) during joint operations and exercises.

METOC Support Team (MST) - MSTs are task organized and equipped to provide a limited level of METOC support to combat elements other than the ACE (e.g. CE, GCE, and CSSE) and are assigned to support MEU operations. It is capable of rapidly deploying as part of a first-in level of METOC support response to a crisis and can be easily integrated into an Air Contingency MAGTF (ACM). Additionally, the MST can be assigned to augment a JMFU during joint operations.

Each MWSS within the MAW is structured and organized to provide one MST that consist of one METOC officer, two forecasters, and two observers. When deployed, the MST will normally be assigned to the G/S-2 (Intelligence) division/section of the supported combat element or MEU. The MST deploys with rugged, ancillary environmental collection and data processing equipment. During operations they organically collect METOC products, data, and information from the nearest deployed MetMF(R), Navy METOC OA Division afloat, host nation or other METOC support organizations and agencies to satisfy METOC information requirements.

Specialized METOC Support

The Marine Corps' Chemical Biological Incident Response Force (CBIRF) was established in 1996 as a result of

Figure 3-DOD-15. CH-53 Sea Stallions from Marine Heavy Helicopter Squadron 769 set course for their next destination after receiving fuel from Marine Wing Support Squadron 473 at Forward Operating Base Salerno, Afghanistan.

Presidential Decision Directive (PDD) 39 to manage the consequences of Nuclear, Biological, and Chemical (NBC) materials or weapons used by terrorists. This national level asset is part of the re-activated 4th Marine Expeditionary Brigade - Anti-Terrorism (MEB-AT) located at Indian Head, Maryland. It is comprised of specially trained and equipped Navy, Marine, and civilian personnel who can rapidly be forward deployed and/or respond to a credible threat of a Chemical, Biological, Radiological, Nuclear, or High Yield Explosive (CBRNE) incident in order to assist local, state, or Federal agencies and designated Unified Combatant Commanders in the conduct of consequence management operations. Within the S-2 (Intelligence) section, permanently assigned METOC forecasters provide specialized NBC dispersion forecast products and services that aid mission accomplishment of this organization.

METOC Support Doctrine

Marine Corps Warfighting Publication (MCWP) 3-35.7, MAGTF Meteorological and Oceanographic Support, provides more detailed information about the Marine Corps METOC Service. An electronic copy is available for viewing and downloading from the Marine Corps Combat Development Command (MCCDC), Doctrine Division web site at https://www.doctrine.quantico.usmc.mil/.

ARMY TRANSFORMATION

The United States Army is undergoing a historical transformation from a division-centered Army poised to fight a cold war, to a smaller, brigade based Army ready to engage in any conflict around the globe. Not only is today's threat to our security more complex and more unpredictable than that of the past, but it is one that could also arise anywhere in the world. Speaking to this threat, the 2005 Army Posture Statement addresses four major areas:

- restructure from a division-based to a brigade based force,
- rebalance the active and reserve forces,
- stabilize the force, and
- reengineer the Army's business processes to facilitate the implementation of the first three areas.

Modularity (transforming from a division-centric to a brigade-centric force) is the most visible aspect of Army transformation to the weather community at large. Modular units will be more compact and more deployable than the current division sized units. Implementing a modular force will provide the Army more time to train, provide predictable deployment schedules, and will provide the continuous supply of landpower required by the Combatant Commanders and civil authorities. The force, above the brigade level, will be supported by similarly modular supporting brigades that provide aviation, fires, logistics, and other support.

Transformation to a modular Army dictates changes in both weather support requirements and how weather is provided to units of action. Resized weather teams will rely more on "reach back" capabilities to obtain pertinent meteorological data. The Army and Air Force are working together to determine the optimal weather team sizing, equipment and communications capabilities required to support these new Brigade Combat Teams.

OPERATIONAL EQUIPMENT AND SUPPORT MISSIONS

Although it is transforming to a modular force, the existing weather support structure within the U.S. Army is a mix of Army and USAF personnel and equipment according to Army-Air Force agreement (Army Regulation (AR) 115-10/Air Force Joint Instruction (AFJI) 15-157, Weather Support for the U.S. Army, 30 June 1996). This joint regulation describes the Service responsibilities and those of Major Army Commands (MACOMs) within the Army for providing weather support. The U.S. Army provides direct weather support to two Army missions: upper air observations for Field Artillery fire support, and limited surface weather observations to support Army weapon systems forward of Division tactical operations centers. Air Force (AF) Major Commands (MAJCOMs) provide operational weather services to war fighting MACOMs in combat, contingencies, and peacetime training. U.S. Army Forces Command (FORSCOM), U.S. Army Europe (USAREUR), U.S. Army Pacific (USARPAC), U.S. Army Special Operations Command (USASOC), Eighth U.S. Army (EUSA), and U.S. Army Training and Doctrine Command (TRADOC) have AF Weather personnel providing daily installation and tactical weather support. Army Artillery Meteorological (ARTYMET) Crews provide direct upper air observation support to artillery units in the same MACOMs. During peacetime training and activation, the Air National Guard (ANG) provides AF operational weather support to the U.S. Army Reserve (USAR) and Army National Guard (ARNG), collectively designated the Reserve Component (RC). In addition, during exercises and contingencies, the ANG may augment the active Army Battlefield Weather forces.

The Army also provides the operational weather support to Army Research Development, Test and Evaluation (RDTE) ranges, centers, and other research facilities using the Developmental Test Command's (DTC) Meteorological Teams (MET Teams) and U.S. Army Space and Missile Defense Command (SMDC) contractors. DTC operational support is established under Army Test and Evaluation Command. SMDC provides weather support to the Ronald Reagan Ballistic Missile Defense Test Site at Kwajalein Atoll through a Meteorological Environmental Test Support contractor.

The Army provides the tactical field and communications equipment to USAF weather forces for tactical operations. The Integrated Meteorological System (IMETS) is the U.S. Army's tactical weather communication, intelligence, and information system providing digital weather support to the commanders and staffs of tactical units, from Echelons Above Corps (EAC) to aviation battalions. The Communications and Electronics Command (CECOM) and Army Research Laboratory (ARL) provide fielding and technical support to Program Director (PD), IMETS and to Field Artillery meteorology programs.

ARTYMET Crews are assigned to Artillery units at Division level, to Field Artillery Brigades, and to Separate Brigades with a direct support Artillery Battalion. Army soldiers regularly take tactical upper air observations to support Field Artillery units during tactical training exercises, at permanent Army Artillery Ranges, or during the full range of combat missions. ARTYMET Crews also take limited surface observations at tactical locations on an "as needed" basis to support artillery operational requirements.

ARTYMET Crews in the Active Component (AC) and RC sections currently use the Meteorological Measur-

ing Set (MMS), AN/TMQ-41, to take upper air observations during tactical operations. It is a mobile, upper air sounding system mounted on a High Mobility Multipurpose Wheeled Vehicle (HMMWV). The MMS provides upper air data to the Field Artillery Tactical Data System for use in adjusting artillery fire (Figure 3-DOD-16), to USAF BWTs, and to the Chemical Officer for use in smoke and in Nuclear, Biological and Chemical (NBC) defense operations. The U.S. Army Field Artillery School (USAFAS), Fort Sill, OK develops requirement documents and is the combat and training developer for meteorological equipment used for Field Artillery support.

Figure 3-DOD-16. Accurate wind profiles are essential for the Artillery to engage their targets. Photo courtesy U.S. Army.

Headquarters, Department of the Army, Office of the Deputy Chief of Staff, G-2, is responsible for Army weather support policy. The Office of the Deputy Chief of Staff, G-3, is responsible for validating and prioritizing weather support requirements and programs to meet Army requirements. In addition, an Army Intelligence Officer at the Air Force Weather Agency (AFWA) at Offutt AFB, NE, serves as a consultant to AFWA for Army weather requirements.

ARMY OPERATIONAL SUPPORT PROVIDED BY THE AIR FORCE

Under AR 115-10/AFJI 15-157, the AF provides the Army with the necessary manpower and unique tactical and fixed weather equipment to meet Army tactical and garrison active component (AC) and reserve component (RC) support requirements. Army support manpower requirements are sourced from AF active, reserve, and ANG weather forces. While direct support of the Field Artillery remains an Army responsibility, and is supported by Army ARTYMET teams, AF Battlefield Weather forces provide supplemental information to artillery crews in contingencies for areas beyond direct ARTYMET observation capabilities. The AF assigns AF weather personnel to the war fighting MACOMs at theater, corps, division, armored cavalry regiments, aviation brigades, separate brigades, and Special Forces groups/ranger regiments to provide direct, on site weather support. AF operational weather squadrons (OWSs) and post-level weather organizations provide garrison and tactical weather warning, observing, forecasting, special support, and staff weather officer (SWO) services to Combat, Combat Support, and Combat Service Support units throughout the peacetime/war continuum (Figure 3-DOD-17). Peacetime garrison activities include supporting flying operations at Army Airfields and severe weather watch, warning, and advisory services for aircraft and post resource protection. Per Army-AF agreement, the AF is responsible for installation, operation, and maintenance of standard AF meteorological and observing equipment at Army Airfields. Tactically, the Army is responsible for vehicles, tactical communications, and weather effects criteria. The Army's IMETS is fielded for these purposes and is operated by AFW personnel. The Army also maintains IMETS hardware and software, with the AF maintaining AF software that performs meteorological functions within IMETS. IMETS uses AF meteorological software, but IMETS is hosted on an Army vehicle, uses Army tactical communications and Army weather effects software. IMETS baseline software is hosted on Army Common Hardware and is Defense Information Infrastructure Common Operating Environment (DIICOE) and Joint Technical Architecture - Army (JTA-A) compliant. The Army provides other tactical equipment to AF BWTs through an Army Table of Organizations and Equipment (TOE). The following paragraphs describe weather activities within Army MACOMs.

EIGHTH U.S. ARMY

Eighth United States Army (8th U.S. Army) requires and uses Army resources to conduct two major meteorological services in direct support of Army operations: collecting and disseminating upper air observations for artillery support, and collecting and disseminating limited surface weather observations to support all tactical

Figure 3-DOD-17. Reliable wind forecasts are necessary to ensure safety during airborne operations.(Photo courtesy U.S. Army).

units and operations.

Two ARTYMET crews with the Second Infantry Division use AN/TMQ-41 Meteorological Measuring Sets to collect upper air observations for direct use by field artillery units. ARTYMET crews also collect routine (usually daily) upper air observations for training; these observations are typically fed into the global weather database.

Additionally, under the Forward Area Limited Observing Program (FALOP), Army personnel use tactical weather kits to collect limited weather observations in data sparse, forward areas. Observations are typically collected by intelligence personnel at brigade and battalion tactical operations centers (TOC) during contingencies or exercises and, in turn, are disseminated to and through USAF weather organizations supporting Army air, ground, or special operations.

USAF weather personnel assigned to the 607th Weather Squadron (607 WS) provide fixed and tactical weather support to 8th U.S. Army units. The 607 WS provides garrison and tactical weather observing, advisory, mission forecast, special support, and staff weather officer (SWO) services during contingency, exercise, and armistice operations. 607 WS organizations provide direct, on-site support at eight 8th U.S. Army installations and at deployed locations. Support is focused on air, ground, special operations, and other combat and combat support missions. In late FY 2002, 607 WS transferred armistice theater forecast responsibility to the 20th Operational Weather Squadron (20 OWS) at Yokota Air Force Base in Japan. The 8th U.S. Army Battlefield Weather forces are primarily responsible for providing observations and tailored mission execution forecasts based on 20 OWS overarching forecasts. Lead METOC support during exercises and contingencies remains with the 607 WS detachment supporting USFK/CFC through the Combined METOC Forecast Unit, in close coordination with the 20th OWS. In FY 2006, 607 WS provides 76 trained weather personnel and requires fixed and tactical weather sensing, data processing, and communications equipment. 8th U.S. Army provides USAF weather units needed garrison and tactical communications, tactical vehicles, MTOE and CTA equipment, and operating funds (for expendables, maintenance, etc.) IAW AR 115-10/AFJI 15-157 (June 1996).

UNITED STATES ARMY EUROPE AND SEVENTH ARMY

United States Army Europe (USAREUR) and 7th Army require and use Army resources to provide meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observations for artillery support and collecting and disseminating limited surface weather observations to support all tactical units and operations.

The Air Force's 7th Weather Squadron (7 WS) provides USAREUR/7th Army in-garrison and tactical weather intelligence and support. This includes observing services for in-garrison operations, contingency and exercise operations, SWO services, and specialized support. The United States Air Forces in Europe (USAFE) OWS at Sembach AB, Germany, provides operational-level forecast products for the European Command Area of Responsibility, to include all USAREUR units. Detachment and operating locations located at V Corps and its aviation assets, 1st Infantry Division and its aviation brigade, 1st Armored Division and its aviation brigade, Southern European Task Force, and 7th Army Training Command, as well as 7 WS supporting 7th Army, evaluate and tailor these forecast products to produce mission execution forecasts.

Figure 3-DOD-18. Weather plays an important role in day to day Army operations, such as this bridging operation in South Korea. (Photo courtesy U.S. Army)

The mission of 7 WS and its 11 detachments and operating locations is to provide weather operations support to the Army's garrison and war operations. Additionally, 7 WS conducts weather operations and planning to meet future Army transformation and modularity initiatives. 7 WS will match the deploying weather force structure to the mission that USAREUR is called upon to execute. 7 WS will tailor its assigned weather forces to meet requirements of the new USAREUR structure and utilize "reachback" capabilities to the maximum extent possible to minimize the fielded footprint without compromising weather operations.

Seven IMETS have been fielded within USAREUR (V Corps, two divisions and their aviation brigades, and two separate brigades. The IMETS is geared to interface as a module of the Army Battlespace Control System (ABCS) to inject weather decision products into the common battle picture for Army commanders. IMETS Light was fielded in Oct FY 2005 to Aviation Brigade weather teams, and an upgrade (version 6.4) is expected to be fielded in FY 2006. This version will improve standard data ingest capability and increase the value of weather information available in ABCS.

USAREUR provides supporting USAF weather forces with tactical vehicles, MTOE and Common Table of Allowances (CTA) equipment and operating funds (expendables, maintenance, etc.). Four ARTYMET sections collect upper air observations for direct use by field artillery units. The Forward Areal Limited Observing Program consists of Army personnel taking limited observations at forward areas in the battlespace. USAREUR G2 has funded purchases of handheld weather sensors for use in FALOP training and equipping Army teams to provide limited weather data at Forward Operating Bases and Forward Arming and Refueling Points. These additional "eyes forward" provide critical information that benefits flight safety as well as the theater weather sensing strategy without having to forward deploy more people to austere locations.

U.S. ARMY SPECIAL OPERATIONS COMMAND (USASOC)

Weather support to USASOC allows commanders to improve efficiency, effectiveness and safety of operations for USASOC units. The 10th Combat Weather Squadron (10 CWS) personnel use tactical weather kits to collect limited weather data and provide limited scope meteorological observations from permissive, semi-permissive and uncertain environments in direct support of Army Special Operations Forces (ARSOF). The 10 CWS Combat Weathermen collect weather data at the deployed team level. These observations are passed to operating bases for use by ARSOF commanders and staff, as well as Air Force Special Operations Command (AFSOC) and Air National Guard (ANG) weather personnel. AFSOC personnel providing direct support to USASOC units are assigned to the 10 CWS, OL-A, 320 Special Tactics Squadron (STS), OL-A 321 STS, and OL-A 353 Special Operations Group. ANG personnel providing direct support to USASOC when activated are assigned to the 107th Weather Flight (Michigan ANG), 146th Weather Flight (Pennsylvania ANG) and 181st Weather Flight (Texas ANG). These weather flights provide garrison and tactical support to USASOC units including the United States Army Special Forces Command and the seven subordinate Special Forces Groups (SFG); the 75th Ranger Regiment, the 160th Special Operations Aviation Regiment, the United States Civil Affairs and Psychological Operations Command (USCAPOC); all SFG and regimental subordinate battalions, and two separate aviation companies. Weather support includes: climatology and solar/lunar illumination tables and studies; courses of action and mission impacts analysis; weather watch/warning services; mission execution forecasts; flight weather briefings; drop/landing zone forecasts; training to ARSOF; training of host

nation and indigenous forces on conducting limited observation programs; surface, upper-air and tactical radar observations; and Foreign Internal Defense analysis, surveys and training. AFSOC Special Operations Weather Teams (SOWTs) are the DOD's sole source for high-fidelity METOC intelligence data collection from permissive, hostile, or uncertain environments. AFSOC provides staff weather support to USASOC, U.S. Army Special Forces Command (Airborne) and the U.S. Army John F. Kennedy Special Warfare Center and School.

USASOC plans and expends resources for operational and administrative support to Air Force Special Operations Command SOWTs providing meteorological service support to USASOC components. USASOC provides funding for required training beyond standard AF weather training, office and deployable automation systems and connectivity to local networks; dedicated tactical communications systems; operations and maintenance/sustainment to support USASOC requirements; funding for Temporary Duty for USASOC requirements; and some organizational clothing and individual equipment. Additionally, USASOC covers expenditures for tactical equipment items such as NBC equipment; communications; Army developed and procured meteorological equipment, power, vehicles, and life support equipment required to accomplish USASOC weather support missions; and maintenance and supplies for USASOC provided equipment. Seventeen Integrated Meteorological Systems-Light (IMETS-L) have been fielded within USASOC. IMETS-L provides a mobile automated weather data receiving, processing and dissemination system to USAF SOWTs. IMETS-L also provides digital weather support, real-time tailored weather information, forecasts, and weather effects on friendly and hostile weapons systems. USASOC also provides funding for facilities, office space, office furniture, and real property to house supporting special operations weather units, as well as secure storage of required equipment.

UNITED STATES ARMY PACIFIC (USARPAC)

United States Army Pacific (USARPAC) uses Army resources to conduct meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observations for artillery support and collecting and disseminating surface weather observations to support tactical units and operations.

USARPAC provides supporting USAF forces with tactical vehicles, MTOE and Common Table of Allowances (CTA) equipment and operations and maintenance funds.

The IMETS and New Tactical Forecast System (NTFS) have been fielded within USARPAC as the primary meteorological equipment for deployed operations. The 25th Infantry Division (Light) (25ID(L)) was given two IMETS-L units ahead of schedule for its year-long deployment to Iraq. The IMETS and NTFS reachback for data via Army provided NIPRNET and SIPRNET conduits.

There are three subordinate commands within USARPAC: United States Army, Hawaii (USARHAW), United States Army, Alaska (USARAK), and United States Army, Japan (USARJ).

The 17th Operational Weather Squadron (17 OWS) provides HQ USARPAC with garrison and tactical weather warnings, forecasts, special support, and SWO services during contingencies and humanitarian operations. Additional Battlefield Weather forces aligned with U.S. Army Japan (USARJ), U.S. Army Hawaii (USARHAW) - including the 25th ID (-) -- and U.S. Army Alaska (USARAK), including 172 SIB, provide direct, on-site support at five USARPAC installations. The weather forces also deploy with their supported Army units, providing tailored battlefield observations and forecasts. AFW reengineering has reduced the requirement for forward deployed weather personnel, instead leveraging IMETS and other recently fielded technology for reachback capability. 17 OWS provides regional weather support, allowing the forward deployed forces to focus on specific area and target forecasts.

The 20th Operational Weather Squadron (20 OWS) at Yokota AB, Japan, provides operational-level forecast products for the USFJ and USFK AORs, to include all USFJ and USFK Air Force and Army units. This includes specific resource protection support (i.e. weather advisories, warnings, and watches), as well as Terminal Aerodrome Forecasts for selected units. The 20 OWS Commander serves as USFJ's Staff Weather Officer (SWO), and also serves as the USARJ SWO. Day-to-day support for Camp Zama, Japan is provided by an Operating Location (OL) under the AF 374th Operations Support Squadron at Yokota AB. The OL on-site at Camp Zama provides observational support and produces mission execution forecasts to support aviation operations.

The 11th Operational Weather Squadron (11 OWS) at Elmendorf AFB, AK, provides operational-level forecast products for the Alaskan Command AOR, to include all USARAK units. The Commander, 11 OWS, serves as the CG, USARAK's Staff Weather Officer. Additionally, 11 OWS is responsible for Terminal Aerodrome Forecasts for Fort Wainwright, along with resource protection weather support (i.e. weather advisories, warnings, and watches) for Forts Wainwright, Greely, and Richardson. The 11 OWS provides flight weather briefing support, as required, to Army, Army Reserve, and Army National

Guard aviation assets in theater. An AF Battlefield Weather personnel (3 ASOS/WE) is collocated with the 172d Infantry Brigade (Separate) (172d Stryker Brigade Combat Team (172 SBCT) at Fort Wainwright and the aviation assets of 4th Battalion, 123d Aviation Regiment. 3 ASOS/WE provides weather support for both tactical and garrison operations, observes the atmosphere and evaluates, then tailors, forecast products to produce Mission Execution Forecasts and staff briefings. After the SBCT conversion, 172 SBCT will include tactical unmanned aerial vehicles (T-UAVs), whose operators will also be receive their weather support from 3 ASOS/WE. The Alaska Army National Guard operates the airfield at Fort Richardson.

U.S. ARMY FORCES COMMAND (FORSCOM)

Weather support to the U.S. Army Forces Command (FORSCOM) is diverse and demanding. FORSCOM, the Army's largest major command, requires and uses Army resources to conduct meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observations for artillery support and collecting and disseminating limited surface weather observations to support all tactical units and operations. FORSCOM consists of more than 750,000 Active Army (AA), U.S. Army Reserve (USAR) and Army National Guard (ARNG) soldiers. These soldiers account for more than 80 percent of the Army's combat power. FORSCOM trains, mobilizes, deploys, and sustains combat ready forces capable of responding rapidly to crises worldwide. The AA component of FORSCOM has nearly 200,000 soldiers. Third U.S. Army is the Army component of U.S. Central Command (USCENTCOM), which is the Joint command responsible for Southwest Asia (SWA), the Persian Gulf, and the Horn of Africa. U.S. Army South (USARSO) serves as the Army component to U.S. Southern Command (USSOUTHCOM). USARSO relocated from Fort Buchanan, Puerto Rico, to Fort Sam Houston, Texas, in CY 2003 and became a FORSCOM major subordinate command October 1st, 2003. FORSCOM also commands three Army Corps: I Corps at Fort Lewis, Washington, III Corps at Fort Hood, Texas, and XVIII Airborne Corps at Fort Bragg, North Carolina. Together they include six divisions, two armored cavalry regiments, five separate brigades and a range of other corps combat, combat support and combat service support units. Two Continental U.S. Armies (CONUSAs), First U.S. Army and Fifth U.S. Army, are responsible for training, mobilization, and deployment support to Reserve Component units in FORSCOM. Another major subordinate command to FORSCOM, the U.S. Army Reserve Command (USARC), commands all U.S. Army Reserve units in the continental United States except those assigned to Special Operations Command. FORSCOM's Army Reserve strength stands at approximately 196,000 soldiers. USARC units are part of the Federal force and make their primary contribution to FORSCOM combat power in combat support and combat service support specialties such as medical, civil affairs, transportation, maintenance and supply.

The ARNG provides FORSCOM a balanced force of 8 National Guard combat divisions, 15 enhanced separate brigades, extensive combat support, and combat service support units. The current FORSCOM ARNG strength is approximately 367,000 soldiers.

The Army is in a period of transformation, over the next several years the Army will transform from its current structure to a structure that has two higher headquarters replacing existing divisions, corps and echelons above corps. This transformation is requiring AF weather to retune its service approach to Army units in terms of manpower and functions.

Weather support to FORSCOM's AA units comes from dedicated AFW forces aligned under three Air Support Operations Groups (ASOGs) within Air Combat Command (ACC): 1 ASOG at Fort Lewis, Washington; 3 ASOG at Fort Hood, Texas; and 18 ASOG at Pope AFB, North Carolina. A weather squadron under each ASOG supports the Corps. Each Army division normally has dedicated AFW forces aligned under an Air Support Operations Squadron (ASOS) or one of the weather squadrons, at their respective installations. Corps and division weather forces are authorized personnel and equipment to support a variety of missions at the various Army echelons. Weather support at each Army echelon is provided according to Army Field Manual 34-81, and Air Force Joint Pamphlet 15-127. Currently, there are nearly 350 AFW authorizations supporting various echelons across FORSCOM. These personnel, enabled by an operational weather squadron, provide garrison and tactical weather warning, observing, mission execution forecast, special support, and SWO services during peacetime, combat, contingency, exercise, or armistice operations.

Air Combat Command (ACC) weather organizations provide direct, on-site support at 11 major Army installations, including the National Training Center at Fort Irwin, California, and the Joint Readiness Training Center at Fort Polk, Louisiana and at deployed locations. Support is focused on air, ground, special operations, and other combat and combat support missions.

FORSCOM provides supporting AFW forces with a Modified Table of Organization and Equipment (MTOE) and operating funds (expendables,

maintenance, etc.). ARTYMET requirements in FORSCOM increased from 17 to 20 sections in FY 2005 due to modularity. These 6-person sections, comprised of Army weather personnel, collect upper air observations for direct use by field artillery units. Six more teams are planned to be added in FY 2006 - FY 2007.

The AF's New Tactical Forecast System (N-TFS) is the primary in-garrison and tactical weather equipment for receiving graphics and alphanumeric data. Data is received via the Very Small Aperture Terminal (VSAT), Tactical VSAT (T-VSAT), Non-Secure Internet Protocol Router Network, and Secure Internet Protocol Router Network. Nineteen IMETS and 15 IMETS-Lights, developed by the Army Research Laboratory, have been fielded within FORSCOM. FORSCOM has also fielded commercial Automated Weather Observing Systems at Yakima Training Center Washington, Fort Campbell, Kentucky, and Georgetown Bahamas.

TRAINING AND DOCTRINE COMMAND (TRADOC) PROGRAMS

Headquarters (HQ) TRADOC is responsible for development and management of weather training programs, Army and Joint weather support doctrine (concepts and field manuals), and the establishment of requirement documents for Army tactical weather support. HQ TRADOC is the approval authority for Army-AF weather doctrine, Army weather system requirements, and weather support policy. Key mission areas for the next few years will be to coordinate weather requirements to the Army's Modular Forces; help develop new weather support doctrine, concepts, and tactics, techniques, and procedures; ensure weather, weather effects to operations, and weather support processes/procedures are properly trained across the TRADOC schoolhouses.

The IMETS continues as the state of the art Army weather support system. However, over the next few years its capabilities will be consolidated into the Air Force's Joint Environmental Toolkit (JET) program. The Army will retain research and development efforts related to Army-specific weather support challenges and will be responsible for interfacing JET with Army battle command systems. Initial JET fielding is programmed to begin in FY 2006.

TRADOC Schools and Battle Labs:

• The U.S. Army Intelligence Center and Fort Huachuca (USAIC&FH) is the functional proponent for Army tactical weather support. USAIC&FH represents the Army warfighter by collecting weather support requirements and developing solutions to satisfy those requirements. A key component to providing weather support to the Army is IMETS, fielded by the Army and operated by AFW forces. The USAIC&FH SWO advises the Army Research Lab, USAIC&FH, and AFW on Army weather support issues and helps develop solutions to meet both active and reserve forces' weather requirements. In addition, the USAIC&FH SWO conducts and monitors weather/weather support training to Army Military Intelligence personnel and AFW personnel supporting the Army. The USAIC&FH SWO is assisted by two active duty AFW personnel that support Army concepts, architecture and requirements initiatives; one civilian contractor that manages the Battlefield Weather course; and one Army Government Civilian that serves as the assistant TRADOC Systems Manager for IMETS. This year the USAIC&FH Weather Team drafted the Statement of Requirements (SOR) for Weather Support to the Army's Modular Forces, and they continued to update and expand the weather effects critical threshold value database to be incorporated into the Integrated Weather Effects Decision Aid (IWEDA). The USAIC&FH SWO also updated the IMETS requirements documents as the program went through several acquisition milestones culminating in Joint Requirements Oversight Council (JROC) approval. In FY 2008, the IMETS Program Office will move under the Program Executive Office - Intelligence, Electronic Warfare & Sensors (PEO-IEW&S) as part of the Distributed Common Ground System-Army (DCGS-A) program.

• The USAF SWO at the Army's Combined Arms Center (CAC) is the primary overseer of the Tables of Organization and Equipment (TOE) for BW forces supporting Army operations. The CAC SWO also arranges

Figure 3-DOD-19. The Integrated Meteorological System - Light (IMETS-L). (Photo courtesy U.S. Army.)

for or provides environmental data, concepts of operation, and weather subject matter expertise for programs, projects, and studies conducted by the TRADOC System Manager - Army Battle Command System, the Battle Command Battle Lab-Leavenworth, the Center for Army Lessons Learned, the TRADOC Assistant Deputy Chief of Staff for Intelligence -Threats, the Foreign Military Studies Office, and the TRADOC Analysis Center-Leavenworth. Other key CAC SWO tasks are to develop weather/weather effects scripts and climatology packages to support modeling and simulation efforts of the Battle Command Training Program (BCTP) and the National Simulation Center, and to provide Army weather support instruction at the Command and General Staff College (CGSC).

• The U.S. Army Field Artillery School (USAFAS), Fort Sill, OK is the proponent for upper air meteorological support to the Army. Artillery meteorological crews, Active and Reserve, had used the AN/TMQ-50 to measure surface weather parameters. Tactical reliability issues forced an Army-wide 'STOP-USE' of the AN/TMQ-50 at the end of FY 2003. Artillery meteorological crews currently use manual surface instruments to measure surface weather conditions. The AN/TMQ 55 (TACMET) has been identified to replace the AN/TMQ 50. The AN/TMQ-41 Meteorological Measuring Set (MMS) is utilized to take upper air observations. The MMS provides weather data to the Field Artillery Tactical Data System for ballistic calculations; to USAF BWTs for weather forecasting; and to the Chemical Officer for obscurant deployment, and Nuclear, Biological, Chemical (NBC) defense operations. Active unit's MMSs will be replaced by the AN/TMQ-52 Meteorological Measuring Set Profiler (MMS-P). The MMS-P is scheduled to begin fielding in early FY 2005. The MMS-P is a suite of meteorological sensors and associated software/models which will provide the Field Artillery with current and/or expected weather conditions at a point where the weapon munitions is expected to engage a target (Target Area Met).

Figure 3-DOD-20. Meteorological Measuring Set- Profiler (MMS-P) (Photo courtesy U.S. Army.)

• The Engineer School (USAES), Fort Leonard Wood, MO coordinates weather support requirements for Terrain Analysis and Topographic Engineering. USAES develops methods of measuring and forecasting state of the ground for trafficability assessments using input weather data fields. Their mission also includes identifying, and documenting requirements to interface meteorological and engineer battlefield systems. Due to force cuts, USAES no longer has a full time civilian meteorologist in the Terrain Visualization Center, DCD, but does have an instructor at the Terrain School at Ft Belvoir to teach weather effects on cross-country mobility and engineer missions.

• The U.S. Army Aviation Center (USAAVNC) at Fort Rucker, AL incorporates weather instruction and procedures into rotary-wing training programs in their mission areas. The Center has requirements for weather observations and USAF forecast support at Cairns Army Airfield, Troy Municipal Airport (MAP), Alabama, and Andalusia MAP, Alabama. Additionally, Fort Rucker operates observing and communications equipment to relay weather intelligence and resource protection advisories to numerous Army remote training sites. Two active duty positions are allocated to provide staff support for Army aviation and aviator training weather issues in areas of curriculum, concept development and doctrine. The USAAVNC SWO also supports the U.S. Army Combat Readiness Center (formerly the U.S. Army Safety Center), Air Traffic Services Command, and other Fort Rucker tenants. Operational weather support for aircrews and resource protection are provided by contractors aligned under ACC.

Beginning in FY 2004, ACC civilianized day-to-day operational weather support to aviation operations at Fort Rucker (Cairns Army Airfield, Troy Municipal Airport, and Andalusia Municipal Airport). ACC, under the same contract, manages garrison air-

field weather services (observing and/or forecasting) at Fort Belvoir, Fort Benning, Fort Knox, Fort Leonard Wood, Fort Huachuca, and Fort Sill.

ARMY NATIONAL GUARD (ARNG) ARTILLERY

In FY 2005, the Army National Guard (ARNG) downsized its Meteorological (MET) Sections assigned to artillery units at Division level, Field Artillery Brigades (DIVARTY), and in Separate Brigades to two 6-soldier teams in the DIVARTY's, except in the Light DIV where there is one team, equaling fifteen 6-soldier teams with 90 soldiers. In the ARNG "Modular Forces", there is one 6-solder team per Fires Battalion in the Brigade Combat Team (BCT), providing 34 teams with six soldiers each, for 204 soldiers. In the Fires BDE there are 3 MET teams per BDE providing 18 teams with six soldiers each, for a total of 108 soldiers. All together the ARNG has 402 soldiers authorized to Artillery Metrological Teams.

The ARTY MET sections provide upper air observations at least 39 training days each year supporting artillery live fire during Annual Training and monthly Inactive Duty Training. The ARTY MET sections support an average of 20 live fire training days and annually expend in excess of 100 balloons per section. The ARNG's ARTY MET Teams use the Meteorological Measuring Set (MMS), AN/TMQ-41A.

ARMY CORPS OF ENGINEERS CIVIL OPERATIONAL ACTIVITIES

The Corps of Engineers (COE) uses a network of about 10,850 land-based gages. About 55 percent of the sites collect meteorological data, 35 percent a combination of hydrologic and meteorological data, and 10 percent hydrologic or water quality data. The Corps funds or partially funds 58 percent (6350) of all the gages it used. Meteorological gages commonly measure precipitation and temperature as a minimum. Most sites also measure hydrological data. All data are used in the regulation of COE dams and other water projects used for flood control, navigation, hydroelectric power, irrigation, water supply, water quality, and recreation. The COE transfers funds to NOAA/National Weather Service (NWS) to collect and maintain precipitation information from 826 of meteorological sites. Similarly, COE transfers funds to the U.S. Geological Survey to maintain precipitation data collection from 460 sites, while the COE maintains the rest. Seventy-five percent of all Corps sites provide real-time data via satellite, microwaves, meterbursts, landlines, or radio. Data from COE gauging sites are available to other Federal, state and local agencies. The NWS uses 100 percent of all Corps data. Most of the data is also used by other agencies.

UNITED STATES ARMY SPACE AND MISSILE DEFENSE COMMAND (USASMDC)

The High Energy Laser Systems Test Facility (HELSTF), an USASMDC directorate located on White Sands Missile Range, is an Army element of the DOD Major Range and Test Facility Base with the mission of high-energy laser (HEL) test and evaluation for future Army and sister Service HEL weapons. In addition to HEL systems test and evaluation, extensive use has been made of on-site laser systems to perform damage and vulnerability testing on laser-hardened materials, missile and aircraft components, and assorted battlefield equipment. The atmospheric sciences/meteorological mission is to support HEL testing by providing measurements of atmospheric conditions that are extremely important to propagation of any HEL beam thru the atmosphere. Many unique meteorological instruments are maintained to support this critical data collection for HEL testing (Figure 3-DOD-21). The HELSTF meteorological team also supports critical safety analysis of atmospheric dispersion for the very toxic laser fuels used. Efforts for FY 2006 include work required to modernize the atmospheric measurements and data collection/analysis

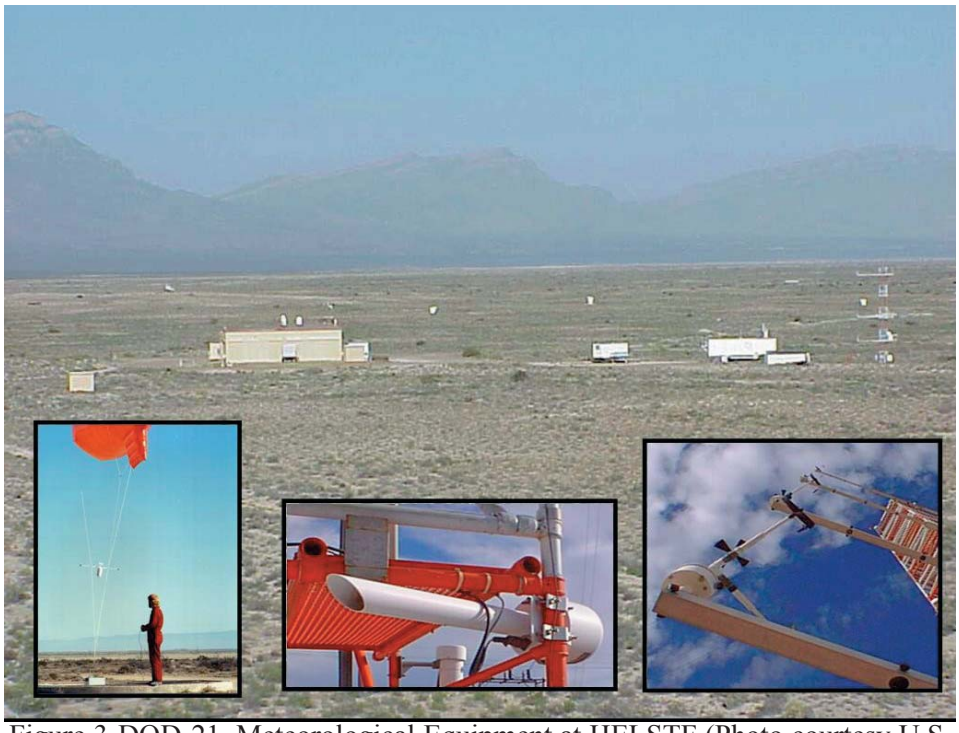

Figure 3-DOD-21. Meteorological Equipment at HELSTF (Photo courtesy U.S. Army.).

capabilities needed to support new laser testing activities.

United States Army Kwajalein Atoll (USAKA) is a subcommand of USASMDC, which provides operational support for the Ronald Reagan Ballistic Missile Defense Test Site (RTS). The RTS meteorological services (Figure 3-DOD-22) support contractor provides meteorological support for range activities including missile operations within the atoll, intra-atoll transportation (marine and aircraft), remote island missile launches including Wake Island, and emergency operations support.

Figure 7. USASMDC is responsible for meteorological support to the Ronald Reagan Ballistic Missile Defense Test Site in the remote Kwajalein Atoll. Photo courtesy U.S. Army.

A full suite of surface and upper air observing equipment is available to support of these operations. Three fixed upper air sounding systems are located on Kwajalein and Roi-Namur. Two portable upper air systems can be deployed to remote locations to provide upper air soundings. Additionally, one dual-polarized -Doppler S-band weather radar and one Doppler C-band weather radar, two DMSP/NOAA satellite receivers (one mobile) both having McIDAS display and management systems, one geostationary satellite receiver, and an intra-atoll mesonet and lightning detection network round out the sensors available to RTS forecasters. RTS, in cooperation with NASA/GSFC, continues to support global climate studies through the Tropical Rainfall Measurements Mission and the follow-on program of Global Precipitation Measurement and a smaller program of monitoring the solar-earth radiation flux for NOAA/ERL.

WEATHER SUPPORT FOR RESEARCH, DEVELOPMENT, TEST, AND EVALUATION (RDTE)

Under Army-AF agreement, the Army has responsibility for weather support for research, development, test, and evaluation (RDTE) to support Army ground combat missions as specified in AR 115-10/AFJI 15-157. The Corps of Engineers (COE), and the Army Materiel Command (AMC) are the major contributors to weather research. The Medical Research and Development Command does research related to soldiers performance in the range of weather conditions expected to be encountered in all theaters of operations. The Army Test and Evaluation Command (ATEC) is responsible for operational meteorological support to Army RDT&E.

CORPS OF ENGINEERS (COE)

The Corps of Engineers (COE) is responsible for reviewing all emerging Army systems for environmental effects, as stated in Army Regulation 70-1. The Topographic Engineering Center (TEC), and the Cold Regions Research and Engineering Laboratory (CRREL), of COE's Engineer Research and Development Center (ERDC), develop Tactical Decision Aids (TDAs) to interpret the impact of weather on terrain to enhance Army operations. TDAs are transitioned to the Digital Topographic Support System (DTSS).

The ERDC has a vibrant, active program of basic research in ecosystem management. Corps of Engineer owned-lands and DOD installations alike are often critical habitat for many species of flora and fauna, acting as virtual sanctuaries for natural resource preservation within otherwise rapidly developing community surroundings. Maintaining, or even increasing, training is paramount to ensuring the effectiveness of today's soldiers. Striking a balance between fulfillment of soldier training needs and protection of our valued ecosystem is a goal of the ERDC research community.

Under its military mission, the Engineer Research and Development Center's Cold Regions Research and Engineering Laboratory, Hanover, NH provides support to Army weapon systems RDTE with all-season solutions for mitigating adverse environmental effects on Army operations. CRREL conducts basic research in sensor signal interaction with snow, ice, and frozen soil, icing accretion on surfaces and structures, deicing technologies, and cold regions surface-air boundary process. CRREL develops databases and models predicting the state of the terrain supporting tactical decision aids such as mobility analysis and sensor performance. Other programs include weather effects on environmental research for military training lands, winter effects on acoustic sensors, mine detection, helicopter pre-flight deicing and airborne icing avoidance, and estimating snow water equivalence for predicting snow melt runoff and potential for flooding.

As part of the ERDC's Battlespace Terrain Reasoning and Awareness (BTRA) research program, researchers are applying the Battlefield Forecast Model (BFM) and MM5 mesoscale weather forecast models to drive CRREL's state-of-the-ground energy budget model, FASST (Fast All-season Soil STrength model). FASST is a physic-based model that provides ground temperature and moisture profiles, freeze/thaw depths, snow depth, and soil strength index based on the terrain/terrain features and the mesoscale weather information. FASST is an integral component of

BTRA, supporting the production of a number of tactical decision aids. BTRA is available to the military services under the Commercial Joint Mapping Toolkit (CJMTK) umbrella. The FASST soil strength information in BTRA provides the geophysical information required to predict mobility for dynamic terrain conditions. The soil temperature and moisture information from FASST is the linchpin for sensor performance predictions. The Region Specific Probability of detection (RSPd) model in BTRA uses the FASST predicted ground temperatures to predict probability of target detection (Figure 3-DOD-23). Unlike tactical probability of detection models, RSPd does not require target tactical level information. RSPp uses the probability of occurrence of radiometric temperatures in the waveband of interest based on the FASST ground temperature predictions and the classical Johnson approach for a generic target to determine the RSPd metric.

ARMY MATERIEL COMMAND (AMC)

AMC is responsible for the design, development, test, and evaluation of equipment to satisfy requirements for meteorological support equipment. AMC provides climatological and meteorological support to RDTE projects involving electro-optics and obscurants. It is also responsible for determining weather effects critical threshold values and environmental sensitivities of battlefield systems. AMC has several Major Subordinate Commands (MSCs) and elements carrying out weather research and development responsibilities including the Research Development and Engineering Command (RDECOM), which has responsibility for the Army's Research Development and Engineering Centers (RDECs) and the Army Research Laboratory (ARL).

The Army Research Laboratory Battlefield Environment (BE) Division has a robust program in developing very high spatial and time resolution characterizations of the lower atmosphere using both measurements and numerical models. This research is particularly focused on the boundary layer for near-surface Army applications and includes characterizing atmospheric aerosols and predicting the effects of the atmosphere on Army systems, sensors, personnel and operations. This research addresses how to assimilate and fuse battlefield observations to update numerical weather model forecasts and to account for higher resolution effects of complex and urban terrain.

The BE Division within the ARL Computational and Information Sciences Directorate (CISD), consists of three Branches split between Adelphi, Maryland and White Sands Missile Range, New Mexico. The three branches combine basic and applied research programs in the areas of meteorological modeling at high resolution and in complex terrain, atmospheric sensing of aerosols and contaminants using laser scattering, spectral analysis, multi-wavelength imagers, and lidars, atmospheric effects including electromagnetic and acoustic propagation modeling, meteorological measurement technologies, and advanced weather impact decision aids. The Division also provides liaison personnel between Army weather R&D and the coupled programs at the Air Force Weather Agency, Air Force Combat Weather Center and the National Polar Orbiting Environmental Satellite System (NPOESS) Integrated Program Office (IPO). These positions focus on coordinating technology transitioned from the BE Division into Army and Air Force fielded systems.

BE Division and the Army PD-IMETS office are partnering with the Air Force in new programs such as the development of a common Joint Environmental Toolkit (JET). The Army IMETS Army Battle Command System (ABCS) 6.4 software and several AFW system software baselines are to converge and transition into a single baseline JET by the end of FY 2005. The JET baseline combines the AF forecast functions with the Army's weather impact Tactical Decision Aid Army unique C2 links to enhance IMETS capabilities for net-centric Army support. IMETS weather products can be accessed through a web-browser, client server applications, or overlaid on the user's Common Operational Picture (COP) through web services such as publish and subscribe (PASS). IMETS technologies will

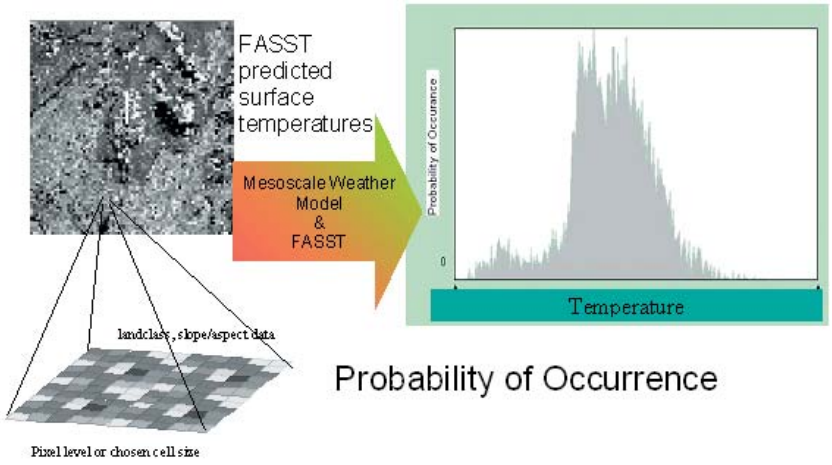

Figure 3-DOD-23. The Region Specific Probability of detection (RSPd) model in BTRA uses the FASST predicted ground temperatures to determine the probability that the temperature of a target of interest is or is not detectable.Photo courtesy U.S. Army.

continue to provide net-centric weather support to Army Battle Command and Future Combat Systems (FCS) as the Distributed Common Ground Station-Army (DCGS-A) Multifunctional Workstation-Weather.

The Meteorological Modeling Branch conducts a research program in the micrometeorological and mesoscale-gamma (small end of mesoscale) processes and structure of the atmospheric boundary layer at scales generally smaller than a few kilometers. This program focuses on the interaction of the land-air interface with wind fields, turbulence, and fluxes. Modeling of aerosol and chemical-biological transport and dispersion in the tactical environment are addressed, including detailed modeling of the boundary layer over complex terrain and within urban domains. A range of numerical weather models is addressed, including non-hydrostatic predictive and diagnostic gridded meteorological models. Diagnostic model output is combined with near real-time observations from lidar, sonic anemometers, and other battlefield sensors to produce rapid refresh analyses for urban domains and complex terrain. Nowcasting and "Weather Running Estimate" products are being developed for the Army Future Force. These are verified against existing numerical weather prediction models and data.

The Atmospheric Effects Branch strives to develop capabilities to measure the battlefield atmosphere in near real-time in a networked environment. They are working on developing methods to manage tactical bandwidth for moving large meteorological data bases, and are producing verified tactical decision aids to assess atmospheric effects and impacts on weapon systems, sensors, and personnel. Weather knowledge management tools are developed for Army C2 and ISR systems including automation of Intelligence Preparation Battlefield (IPB) and integration of various weather effects into ground and aerial vehicle route planning. Controlled field measurements are performed to develop or verify theoretical models for atmospheric and optical turbulence, acoustic propagation, radar propagation, wind flow in small scale urban domains and desert aerosol production. Value added studies are performed to justify Army requirements for higher spatial and temporal meteorological data and model resolution, for the collection of conventional and non-conventional battlefield weather observations, and for the timely dissemination of data.

The Atmospheric Sensing Branch is working to enhance warfighter situational awareness through the utilization of advanced atmospheric instrumentation and novel characterization techniques. They are developing, testing, evaluating, and implementing aerosol classification techniques to enhance identification. They are employing novel polarimetric imaging techniques to analyze effects from surface contaminants for target recognition and identification. This research also includes modeling the effects of forest canopies on acoustic propagation and investigating the use of beamforming techniques for the mitigation of the effects of the atmosphere on sensors, systems, and soldiers.

The Army Research Office, Research Triangle Park, North Carolina, manages the Army's extramural basic research program in the atmospheric sciences. These programs are concerned with understanding the dynamical and physical processes of the atmospheric boundary layer at scales of interest to the Army (millimeters to 10's of kilometers) through measurements, simulations, and theoretical considerations. The basic research program is conducted through the peer-reviewed, individual investigator program and occasional special initiatives. The focus of the research is on the atmospheric processes and effects of the atmospheric boundary layer where the Army operates. Objectives of the research are to develop, from first principles, the physical basis for understanding the boundary layer processes, thereby leading to better understanding of atmospheric effects on soldiers, materials, and weapon systems. The research examines dispersion of battlefield materials, the effects of heterogeneous terrain features on airflow, and the development of natural obscurations throughout the diurnal cycle. An essential element of the research is the development of instrumentation to measure the volumetric fields of wind velocity, temperature, and moisture of the boundary layer at turbulence time scales. Special funding areas are also managed. The Defense University Research and Instrumentation Program (DURIP) provides funds for instrumentation needed to support ongoing research activities. The Defense Experimental Program to Stimulate Competitive Research (DEPSCoR) participation is a competition restricted to universities in certain states that compete for additional basic research funds. Also basic research under the Small Business Innovative Research Program (SBIR) is managed for selected topics. A primary focus continues on the analysis and understanding of the stable boundary layer. New initiatives include acoustic tomography of the atmospheric surface layer and measurement and analyses of wind fields in an urban area.

Communications Electronics Command (CECOM), a major subordinate command of AMC, provides support to developing and fielding weather programs through the following organizations: Logistics Readiness Center (LRC), Research, Development and Engineering Center (RDEC), Software Engineering Center (SEC), and Safety office. The CECOM LRC is the level II manager of the Meteorological Measuring Set (MMS) program.

RDEC's Communications-Electronics Research Development Engineering Center (CERDEC), Intelligence and Information Warfare Directorate provides technical management and support to the Program Manager, Intelligence and Effects and Program Manager, Night Vision/Reconnaissance, Surveillance, and Target Acquisition for the IMETS and the MMS-Profiler. A brief description of each of these programs shows CECOM's involvement.

Meteorological Measuring Set (MMS), AN/TMQ-41. The MMS is an upper air meteorological data collection, processing and dissemination system that provides data to the field artillery and target acquisition users. The system is a non-developmental item (NDI). All active Army units and National Guard Bureau are equipped with the MMS.

The Meteorological Measuring Set-Profiler (MMS-P) AN/TMQ-52 System. The Meteorological Measurement Set-Profiler (MMS-P) is a major improvement over the MMS. The AN/TMQ-52 design will support the new generation of artillery weapons. The system will include frequent and update meteorological messages that enhances the meteorological validity over a larger battle space than the current equipment. The MMS-P uses the MM5 mesoscale meteorological model to assimilate data from a variety of sources to provide the best meteorological messages to the user in a timely fashion. The system receives data from ground-based sources, radiosondes, and satellite-based sources, (such as boundary data from communications satellites and, in a future program block improvement, polar orbiting meteorological satellites) through onboard satellite receiving capability. The data affects the operation of the mesoscale meteorological model and for post-processing of the data in order to generate meteorological messages. Finally, an operator interface, in conjunction with the message generation and formatting software, facilitates communication between the MMS-P and all other systems that require interoperability with the MMS-P. Four System Design and Development (SDD) models have been produced. Developmental testing has been successfully completed and Low Rate Initial Production (LRIP) was approved at a MS C decision in FY 2003. The Profiler system has completed Initial Operational Test and Evaluation (IOTE) FY 2005. Full Rate Production (FRP) was approved at a FRP Decision in FY 2005.

The Intelligence and Information Warfare Directorate (I2WD), Communications Electronics Research & Development Engineering Center (CERDEC), Research Development & Engineering (RD&E) Command is providing technical and acquisition support to the Program Manager, Intelligence & Effects and integrating the Integrated Meteorological System (IMETS) into the Distributive Common Ground Station (DCGS) Spiral 4/5 configuration.

The IMETS comes in two basic configurations known as the Vehicle Mounted (AN/TMQ-40B/C/D) and Light (AN/GMQ-36/36A/36B) groups. The IMETS Vehicle Mounted group (Figure 3-DOD-24) has three variants, all with the same function that differ only by vehicle, shelter, and/or generator. The new IMETS-Light (AN/GMQ-36A) will replace the AN/GMQ-36 versions now in production with a CHS-3 cost savings window base computer. The AN/GMQ-36B is a Command Post version that has all the functionality of the AN/GMQ-36A.

Either the IMETS Vehicle Mounted or the IMETS Light configuration can provide the weather component of the Intelligence Electronic Warfare (IEW) sub-element of the Army Battle Command System (ABCS). IMETS has been designated by the DCGS as the Weather Center for DCGS-A weather requirements and is on track to fully support the Future Combat System (FCS) prime. The IMETS provides commanders at all echelons with an automated tactical weather system that receives, processes and disseminates weather observations, forecasts, battlefield visualization, and weather effects decision aids to all Army Tactical Command and Control System (ATCCS) Battlefield Functional Areas (BFAs). IMETS can receive weather information from geostationary satellites (either USA, European, Japanese, or Chinese civilian) depending on the system's location, civilian forecast centers, the Air Force Weather Agency, artillery meteorological sections and remote sensors. IMETS processes and collates forecasts, observations, and climatological data to produce timely and accurate weather products tailored to the specific war-fighters needs. Significant weather and environmental support to war-fighters are the weather applications such as the automated tactical decision aids and contours client. These weather products display the impact of the weather on current or planned operations for both friendly and enemy forces. Weather products can also be overlaid on the Common Operational Picture (COP) or Common Tactical Picture (CTP) accessed by using a browser, and is executed on the users terminal through weather client implementations.

Major test events in FY 2005 include the IMETS Intra-Army Interoperability Certification test, completed during the First Quarter of FY 2005 at the Central Test Support Facility (CTSF) and the ABCS 6.4 Good Enough (GE) Operational Evaluation (OPEVAL) completed in Second Quarter FY 2005. The AN/TMQ-40C Materiel Release is on schedule to occur at the last quarter of FY 2005 and the AN/TMQ-40D for FY 2006. Both of these systems, along with the AN/GMQ-36 are on schedule to field to units. In order to

Figure 3-DOD-24. IMETS Vehicle Mounted Configuration. (Photo courtesy U.S. Army.)

streamline the acquisition process, the IMETS AN/GMQ-36A/B has been given permission to go directly to Materiel Release pending the results of Development Testing and skip Milestone C pending on Development Testing results. FY 2005 efforts will focus on the ABCS 6.4 GE Operational Assessment and fielding and the IMETS-Light (AN/GMQ-36A/B) Materiel Release and fielding decision, along with finishing the fielding efforts for the AN/GMQ-361 to gaining units including the Stryker Brigade. AN/TMQ-40B/C/D systems will also be fielded during FY 2005.

AMC's Field Assistance in Science & Technology (FAST) Activity provides rapid, successful technical solutions for the Warfighter. With Science Advisors (senior AMC scientists and engineers) located at Major Commands throughout the world, AMC-FAST provides support in a wide range of technical areas. Recently FAST has assisted the 82d Airborne Division Artillery (82nd ABN DIVARTY) by providing a lightweight alternative to their previously used meteorological observation equipment.

The 82nd DIVARTY has units dispersed around the globe in support of the Global War on Terrorism. During the initial stages of deployment, these Airborne units typically have no meteorological (MET) measuring capabilities due to the logistics burden of their observation equipment, which includes several large tripod mounted pieces and one generator. Weighing a total of 23,100 pounds, this equipment requires 3 HMMWVs for transport.

AMC-FAST responded to the 82nd DIVARTY's request by providing them with a lightweight system called the Miniature Meteorological Observation Kit (Mini-Met Kit). The 25 pound Mini-Met Kit is stored in a hard-shell case for protection during air drop, vehicular transport or storage. It can also be removed from the case and transported in one soldier's Alice Pack. The contents of this kit allow DIVARTY MET teams to observe current weather at the firing site and to launch and track pilot balloons (PIBALS) in support of artillery fires.

As the XVIII Airborne Corps Field Artillery (FA) has a similar need for accurate, lightweight, man-portable MET equipment, AMC-FAST provided funding for 9 Mini-MET systems total; 4 to be evaluated in the field by the 82d DIVARTY and 5 by the XVIII ABN Corps FA. In their initial evaluation, the 82nd DIVARTY MET compared results obtained using the Mini-MET kit with those obtained from their older MET equipment. Results were reported to be extremely accurate, with less than 3% differences between the two systems for all readings taken. As this new, lightweight weather observation kit is parachute deployable and transportable by just one trooper, the Mini-MET Kit can truly be viewed as a force multiplier.

To use the Mini-Met kits for actual "Call to Fire" during Artillery missions in theater, formal approval must be given by the Army's Artillery School at Ft Sill. To expedite the Schoolhouse's evaluation & approval, XVIII ABN Corps FA has loaned one of their kits to Ft Sill. They are now awaiting formal approval to use the kit during GWOT missions.

It is anticipated that this AMC-FAST project will yield enhanced capabilities for the 82d Airborne DIVARTY and the XVIII Airborne Corps FA by providing them with a robust means to rapidly and accurately acquire the MET data needed to increase early entry artillery accuracy and lethality.

ARMY TEST AND EVALUATION COMMAND (ATEC)

The Developmental Test Command (DTC), a subordinate command of United States Army Test and Evaluation Command (ATEC), is responsible for providing operational meteorological support to eight Army ranges and test sites. Under responsibilities established in AR 115-10/ AFJI 15-157, the DTC meteorological units provide meteorological data collection and analysis, consultation, and weather forecast and warning services to support Army and other DOD research, development, test and evaluation (RDT&E) activities at the eight Army installations. Funding for the Army RDT&E Meteorology Program under Program Element 665702 is sufficient to maintain the basic meteorological support infrastructure at Army RDT&E ranges and sites. However, instrumentation needed to support unique or test-specific requirements generally must be funded by test sponsors. Because the majority of the operational meteorological support workforce at the Army ranges is or soon will be eligible to retire, the Program has implemented an intern program to recruit and train entry-level scientists and technicians to ensure continuity in specialized meteorological support services as senior employees begin to retire.

The Army RDT&E Meteorology Program has entered into a multi-year working relationship with the National Center for Atmospheric Research

(NCAR) to enhance "range scale" (mesoscale to microscale) forecast and analysis capabilities at the Army test ranges. The principal product of this relationship is the Four-Dimensional Weather (4DWX) System, which consists of a central data archival/retrieval system for all range and external meteorological and model data, a high-resolution mesoscale meteorological model (MM5), and a variety of user-configurable displays. The MM5 mesoscale model is used operationally in both predictive and analytic modes to provide detailed information about the past, current, and future structure of the atmosphere over the Army's test ranges. Recent 4DWX enhancements include the implementation of MM5-based real-time four-dimensional data assimilation (RT-FDDA) capabilities at the major Army test ranges and development of Global Meteorology on Demand (GMOD), a globally-relocatable mesoscale modeling system to support Army RDT&E (including DTC Virtual Proving Ground modeling and simulation) at locations other than the Army ranges. In FY 2006, the 4DWX program will begin transition of its operational mesoscale model from MM5 to the next-generation Weather Research and Forecast (WRF) model. Output from mesoscale model forecasts and analyses is used as meteorological input to atmospheric dispersion, noise propagation, ballistic trajectory, and other range applications models to simulate many tests and their associated impacts. The 4DWX system contributes to improved test planning and conduct, selection of more representative locations for test sensors, inclusion of realistic atmospheric effects in virtual testing, and forensic analyses of meteorological effects on test results.

The Chief of the Meteorology Division at Dugway Proving Ground's West Desert Test Center serves as the Program Manager for Meteorological Support to Army RDT&E. Under Program Element 0605384, the Division's Modeling and Assessment Branch also provides the following specialized services: (1) technical assistance to the DTC operational meteorological teams/branches; (2) atmospheric model verification and validation, including algorithm evaluation and the generation of validation data sets; and (3) technical assistance to the DOD CB defense modeling community in the development of new CB hazard assessment models. Division employees also serve on various national and international committees addressing issues related to meteorological measurements, atmospheric dispersion modeling, and CB hazard assessment.

ARMY MEDICAL RESEARCH AND MATERIEL COMMAND

The U.S. Army Research Institute of Environmental Medicine (USARIEM) conducts basic and applied research on the effects of heat, cold, high terrestrial altitude and nutritional status on the health and performance of individual soldiers and combat crews operating Army systems.

Applied research in thermal physiology and biophysical modeling is directed towards improving soldier performance and minimizing health risks in climatic extremes. The sensitivity of the soldier to local weather parameters (primarily ambient temperature, dew point, wind speed, and solar radiation) defines an operational envelope for unimpaired human performance. The overall goals of USARIEM weather-related research programs are to develop methods to effectively monitor and, where possible, extend the operational envelope for both training and operational scenarios.

Weather-related research efforts include the development and validation of automated methods to integrate thermal strain prediction models with real-time weather information resources relevant to dismounted infantry operations. Temporal and spatial scales of interest are meters to kilometers and minutes to several days. USARIEM is working with the Army Research Laboratory Battlefield Environment Division to implement thermal models on Personal Digital Assistant (PDA) devices and the Integrated Weather Effects Decision Aid (IWEDA).

The availability of ground level environmental data at high temporal and spatial resolution continues to pose a significant challenge for predictive model development and validation. A prototype miniature weather station developed under a Small Business Innovative Research (SBIR) project has been refined into a 1 kg battery powered unit which includes a sonic anemometer. An prototype unit was used to collect data during a study of thermal exposure in August, 2005 at the U.S. Army's Ranger Training Brigade (RTB) Ranger School (Ft. Benning, GA). Work continued on the wireless network-capable, expendable, micro-environmental sensing system which has been expanded to consider new sensor applications.

As part of the warfighter physiological status-monitoring (WPSM) program, USARIEM is investigating methodologies needed to integrate real-time local environmental data and warfighter physiological data with predictive model processes. The effective fusion of these two real-time data streams will enable near term environmental strain and performance status predictions for individual warfighters.

The miniature weather station may be used to collect meteorological data to support the prediction of thermal stress on the WPSM system. Research efforts are intended to address capabilities identified in the Operational Requirements Document (ORD) for the Army's Land Warrior program.